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A QUANTITATIVE STUDY OF THE EFFECTS PRODUCED BY SALTS OF SODIUM, POTASSIUM, RUBIDIUM AND CALCIUM ON MOTOR NERVE OF FROG

ESTHER GREISHEIMER

From the Hull Laboratories of Physiological Chemistry and Pharmacology, University of Chicago

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INTRODUCTION

Mathews (1) in the course of his investigations on the nature of chemical and electrical stimulation found the chloride of rubidium to be the most powerful stimulating agent for motor nerve of frog. Owing to conflicting reports in the literature on the subject, further investigation seemed desirable.

A brief review of the physiological effects of the rubidium salts and the related sodium and potassium salts will be given. Bunsen discovered rubidium in 1861 and knew from the chemical behavior of its compounds that it belonged in the group of alkali metals. In most of its peculiarities rubidium exhibits the greatest similarity to potassium, which it follows in the periodic system. Grandeau (2), however, as early as 1864 concluded that rubidium was more nearly related to sodium than to potassium. He injected 1 gram of the salt dissolved in 15 cc. of water into dogs. If the dog died the salt was considered toxic, but if the animal recovered sufficiently to run about the salt was considered ineffective. Grandeau, by these methods, found potassium alone to be toxic, and sodium and rubidium chlorides to be ineffective, in equal dosage.

Ringer (3) made a comparative study of these chlorides, using the ventricle of the frog's heart, in which he maintained an artificial cir-

culation. On using 1 cc. of a one and two hundred five thousandths (1.205) per cent solution of rubidium chloride in 100 cc. of normal saline solution, he observed the ventricular contractility to grow less and less until it had disappeared. On addition of small amounts of either strontium or calcium chloride (3.5 to 5 cc. of 1 per cent sol. to 100 cc. of the circulating fluid) fair contractions speedily returned. A calcium salt in saline broadened the beat, rounded its top and greatly retarded dilatation. Rubidium, like potassium, obviated these effects, and restored to the beat its normal character.

Blake (4) criticised the work of Ringer because it had been done on the isolated organs of a dead animal. He believed that the physiological action of a salt should be determined by introducing it directly into the veins or arteries of a living animal, so that it could, with the least disturbance possible, be brought into direct contact with tissues whose reactions he wished to investigate. He injected the chlorides of rubidium, potassium and sodium into the veins or arteries of frogs in order to test the effects on the heart. His results differed from those of Ringer in that he found sodium and rubidium to behave similarly and potassium to be exceptional in its behavior, but he failed to give the data obtained.

Harnack and Dietrick (5) injected rubidium chloride subcutaneously into frogs, and compared the results with those following the injection of potassium chloride. These salts did not essentially affect the heart muscle when given in doses of about thirty milligrams. From the results obtained they concluded that the differences between potassium and rubidium salts were quantitative, potassium being the stronger of the two. A few investigations were carried out in which isolated muscle was placed in rubidium or potassium chloride, and a rapid decrease in height of contraction following stimulation followed in either salt. These investigators gave no data from experiments on motor nerve of frog, but simply stated that rubidium salts appeared to affect motor nerve to a slight degree only.

Brunton and Cash (6) observed that "motor nerve was not paralyzed by rubidium except in very large doses." The height of contraction of muscle was increased by rubidium and potassium alike. The lethal activity on frogs of the chlorides used placed the metals in the following series, potassium being the strongest: potassium > rubidium > barium > caesium > lithium > strontium > sodium > calcium.

Richet (7) studied the effects of both subcutaneous and intravenous injections of rubidium and potassium chlorides on fish, frogs, guinea

pigs, pigeons and rabbits. The results were similar on the various animals, rubidium chloride being slightly less toxic than potassium chloride.

Botkin (8) injected these chlorides into dogs and found that rubidium chloride exerted effects similar to smaller doses of potassium chloride.

Grützner (9) has, as had Ranke (10) and Biedermann (11) before him, found the chloride of potassium, even in dilute solution, intensely toxic. In stimulating action, caesium was found most active, rubidium next, and potassium had no noticeable stimulating action at all. But in toxicity potassium stood highest, rubidium next and caesium lowest. Calcium also was found to be toxic to the nerve.

Many investigations on the antagonisms of these salts have been carried out. Loeb (12) found pure sodium chloride a strong poison for many (if not all) marine animals. He considered the poisonous effects due to the sodium ion. Equimolecular solutions of calcium and potassium chlorides were also found poisonous, but a combination of the three ions was not poisonous. Loeb and Cattell (13) showed that eggs of Fundulus poisoned with potassium chloride were unable to recover when placed in distilled water or in a saccharose solution, while they recovered when placed in an $\frac{M}{8}$ salt solution, or in acidified water. The relative efficiency of the salts for inducing the recovery of the heart beat increases, first with the concentration of the salt in the solution, then with the valency of the anion of the salt, the valency effect apparently following Hardy's rule. Loeb and Ewald (14) studied the inhibitory effect of calcium on motor nerve of frog. A portion of nerve immersed in an $\frac{M}{4}$ sodium chloride solution results in twitching of the attached muscle. They found that 2 cc. of an $\frac{M}{8}$ calcium chloride solution per 100 cc. of a $\frac{M}{4}$ sodium chloride are required to suppress these twitchings. On adding a quantity of calcium not quite high enough to inhibit entirely the effect of the stimulating salt, the latent period of stimulation was considerably increased. This fact harmonized with Loeb's assumption that the inhibitory effect of calcium is due to a prevention or a retardation of the diffusion of the stimulating salt into the nerve.

Burridge (15) perfused isotonic sodium chloride through the frog's heart. Stoppage in the dilated condition and loss of electrical irritability followed. Calcium opposed these effects.

Zoethout (16) found that gastrocnemii of frogs were thrown into contraction on immersion in $\frac{M}{8}$ potassium chloride. He showed that

treatment with sodium chloride previously, or the simultaneous introduction of sodium and potassium chlorides, hindered the development of the potassium contraction. A similar treatment with calcium chloride reduces the extent of the potassium contraction, and lengthens the latent period. He used 1 to 10 cc. $\frac{M}{8}$ $CaCl_2$ and 10 cc. of 6 per cent cane sugar solution followed by 1 cc. $\frac{M}{8}$ KCl in 10 cc. 6 per cent cane sugar.

Lillie (17) found that Arenicola larvae lost muscular contractility gradually in pure isotonic solutions of non-electrolytes, such as cane sugar and dextrose. Pure solutions of sodium salts induced well-marked contractions in such larvae, and the addition of calcium chloride (as low as $\frac{M}{25600}$) to sodium chloride solutions, increased the ability of the latter to restore normal contractility. Potassium and rubidium exerted a more vigorous effect than sodium.

Joseph and Meltzer (18) used the gastrocnemius and the sciatic. The muscle in sodium chloride alone stopped contracting after an hour and a half or two hours, while if the solution contained also some calcium, the contractions continued from six to eight hours. In nine out of ten experiments the nerve in calcium chloride lost its conductivity in two or three hours, but sodium chloride caused no loss of conductivity in the sciatic even after many hours.

Groves (19) stated that the various salts of potassium killed the nerve so rapidly that the results were not clear and uniform. Osterhout (20) used young plants of a fresh water alga, Vaucheria sessilis, which can live three to four weeks in distilled water. These plants were killed in a few minutes by $\frac{3M}{32}$ sodium chloride, and in a few days by $\frac{M}{1000}$ sodium chloride. The toxicty of a $\frac{3M}{32}$ solution of sodium chloride was inhibited by the addition of calcium chloride in the proportion of one part of calcium to one hundred parts of sodium. Potassium chloride was also able to neutralize the poisonous effect of the pure sodium chloride.

Burnett (21) continued the work of producing glycosuria in rabbits by the injection of sodium chloride. The usual glycosuria was 0.25 per cent in rabbits with injection of pure sodium chloride, but this was reduced, varying from a trace to 0.03 per cent on injecting $\frac{M}{6}$ sodium chloride to which had been added some potassium. Burnett added 2.2 molecules of potassium chloride per 100 molecules of sodium chloride. Calcium chloride was found equally effective in preventing glycosuria.

Miyake (22) found 25 cc. of $\frac{N}{10}$ sodium chloride plus 5 cc. $\frac{N}{10}$ calcium chloride the most favorable mixture for the growth of rice seedlings. A similar mixture, using potassium chloride in place of calcium chloride was found favorable.

Cramer (23) studied the effects of sodium and calcium salts on the growth of cells of a transplantable mouse carcinoma. The cells were immersed for an hour or two in isosmotic solutions of sodium and calcium chlorides. The subsequent transplantation showed a very distinct inhibition of growth on the part of the cells which had been suspended in calcium chloride. The growth of the cells which had been suspended in sodium chloride showed slight, if any, inhibition. The inhibition of growth produced by the calcium ions can be neutralized by a subsequent suspension of the cells in sodium chloride solution.

Mathews' (1) observations on nerve were more thorough than any of the preceding. He found that all the sodium salts stimulated the motor nerve, and likewise potassium chloride in one-fourth molecular solution or stronger, while solutions weaker than this never stimulated, but very rapidly depressed the nerve. Rubidium chloride was found to be the most powerful stimulant of the chlorides, and the irritability of nerves in this solution was lost very rapidly. In this observation Mathews (1) differed from Grützner (9) who found caesium a more powerful stimulant than rubidium, and from Zoethout (24) who found that nerves were not stimulated on being immersed in rubidium chloride.

Zwaardemaker and Feenstra (25) have made the most recent observations on these related salts. They have found that the potassium in Ringer's solution may be replaced by rubidium, uranium and thorium, and that the necessary quantities are proportional to their radioactivities. Their investigations were made on heart of frog.

Prof. A. P. Mathews suggested that further investigations be carried out on these salts, so the writer undertook a quantitative study of the toxic effects produced in each salt alone, and then in various combinations. These observations have necessarily been limited owing to the great difficulties in procuring rubidium salts. The purpose of this paper is not to set forth an exhaustive discussion on the nature of the nerve impulse, nor on the manner in which salts act, but simply to state the results observed on studying these salts in a thoroughly quantitative manner. The statements that "calcium rapidly depresses the nerve" and that "potassium is very toxic" must be reduced to quantitative terms. It is hoped that these results may be a helpful stepping stone to the next investigator in this line of work.

METHODS

The sciatic nerve and the gastrocnemius muscle of the leopard frog were used. The sciatic was not cut, the whole sacral plexus with an attached bit of spinal column being left intact. It was believed that more constant results could be obtained if nerves were kept as nearly uninjured as possible. The frogs were brought from the tank and the preparation rapidly made, scarcely five minutes elapsing between the pithing of the frog and the mounting of the preparations in the moist chambers. The fact that frogs are in varying conditions of health is a great uncontrollable source of error. Sex appears to make no difference in the results, but the writer believes that humidity will in the future be shown to be an influential factor in nerve work.

A 4 cm. length of nerve nearest the muscle was immersed in a paraffin cup containing 5 cc. of the solution whose effects were to be studied. The nerve as it emerged from the solution was led across electrodes. At first platinum electrodes were used, but it was found that copper electrodes gave results identical with those obtained from the platinum electrodes, hence the use of copper ones was continued. This is contrary to general opinion, but control nerves remaining in Ringer's solution showed practically no decrease in irritability, even after twenty hours, so injury from copper electrodes did not occur to any extent. The remaining portion of the nerve with the attached bit of spinal column was placed in a second paraffin cup containing Ringer's solution. The entire nerve varied from 7 to 10 cm. in length. The cover of the moist chamber was not removed during the experiment, which was often continued for sixteen hours. Every known precaution was taken for keeping the conditions as favorable as possible for the nerve, and as a result the controls in Ringer's solution, run with the daily series of observations, showed very little change, if any, in irritability, even when the experiments were continued over a space as great as eighteen or twenty hours.

Two Edison primary batteries attached in parallel, and renewed from time to time, furnished the current for the primary coil. The coil used at the University of Chicago was of the small type for laboratory use, put out by C. H. Stoelting Company, Chicago. The greatest distance between coils on this type was 21.4 cm. The coil used at the University of Minnesota was put out by W. Oehmke, Berlin. The coils could be separated as much as 75 cm. with this type. Various types of keys were tried out, and the one most suitable was an ordinary wall-switch, conveniently mounted, which apparently gave a constant

break shock. The greatest distance between the coils just effecting stimulation was determined at regular intervals. The increase in the strength of shock, as thus determined, was assumed to be a measure of the toxicity of the salt. The writer recognizes the criticisms of such an assumption, but knows of no improved method at present.

The salts were repeatedly recrystallized and the purity carefully tested. Redistilled water from a block tin condenser was used in making up the solutions. The data for purification are given in detail. The calcium chloride, C. P., was not recrystallized. About 45 grams were dissolved and made up to 250 cc. Then 10 cc. of this solution were diluted to 250 cc., and 50 cc. portions were evaporated and dried to constant weight in Jena dishes. Two samples weighed 0.3114 and 0.3116 gram respectively. This material was then redissolved, heated, and ammonium hydroxide and ammonium oxalate added. The material was kept on the steam bath over night. After filtering and washing, the precipitate was ignited to CaO in platinum crucibles. On drying to constant weight, the CaO weighed 0.1569 and 0.1568 respectively. Then 111 : 56.1 :: X : 0.1568 X = 0.3102 gram $CaCl_2$. The actual weight of $CaCl_2$ was 0.3114, the calculated weight 0.3102 gram, therefore, the impurity was 0.3 per cent.

The potassium chloride had been recrystallized by Miss M. Koch. About 38 grams were dissolved and made up to 250 cc. Of this, 10 cc. were diluted to 250 cc., and then 25 cc. portions taken for analysis. These were evaporated and dried to constant weight in Jena dishes, and two samples weighing respectively 0.1351 and 0.1352 gram were used. This material was then dissolved, potassium chromate added, and titrated with standard $AgNO_3$. The amounts of $AgNO_3$ required were 11.27 cc. and 11.28 cc. respectively. The factor of the $AgNO_3$ was 1.607. Then $11.27 \times 1.607 \times 0.00746 = 0.1351$ gram; $11.28 \times 1.607 \times 0.00746 = 0.1352$ gram. As these were identical with the actual weight, the salt was 100 per cent pure.

The sodium chloride was recrystallized four times. Five cubic centimeters of the stock solution were diluted to 250 cc., and 25 cc. samples were taken. The two samples were evaporated in Jena dishes and dried to constant weight. They weighed 0.0891 gram. This material was dissolved and titrated with $AgNO_3$, using potassium chromate as an indicator. The amount of $AgNO_3$ required was 9.58 cc. Then $9.58 \times 1.607 \times 0.00585 = 0.0900$ gram. The actual weight was 0.0891 gram, hence there was 1.0 per cent impurity.

The sodium bromide was recrystallized four times. About 28 grams

were dissolved and made up to 250 cc. Of this stock solution 10 cc. were diluted to 250 cc., and samples of 25 cc. were taken. The samples weighed 0.1093 gram, on evaporating and drying to constant weight. The material was dissolved and titrated with $AgNO_3$, 6.79 cc. being required for the titrations. $6.79 \times 1.607 \times 0.0103 = 0.1123$ gram. The actual weight was 0.1090, hence the impurity was 2 per cent.

The sodium sulphate was recrystallized four times. About 75 grams were dissolved and made up to 500 cc. Of this, 10 cc. were diluted to 250 cc., and 25 cc. were evaporated and dried to constant weight. The samples weighed 0.1417 gram. This was dissolved, heated and precipitated by adding $BaCl_2$. The precipitate was filtered, washed and ignited to constant weight. The actual weight of $BaSO_4$ was 0.2335 gram. The calculated weight $-(142.16 : 233.46 :: 0.1417 : X)$ was 0.2327. The impurity was therefore equal to 0.3 per cent.

The rubidium chloride was made from rubidium carbonate. After several recrystallizations, about 32 grams were dissolved and made up to 250 cc. Of this 1 cc. portions were evaporated and dried to constant weight. The samples weighed 0.1261 gram. This was dissolved and titrated with $AgNO_3$; 10.59 cc. were required for the titration. The factor for this $AgNO_3$ was 0.985. $10.59 \times 0.985 \times 0.012095 = 0.1261$ gram hence the salt was 100 per cent pure.

The rubidium bromide was recrystallized three times. About 45.5 grams were dissolved and made up to 250 cc. Of this 1 cc. portions evaporated and dried to constant weight. The samples weighed 0.1787 gram. This material was dissolved and titrated with $AgNO_3$, using 11.27 cc. in the titration. $11.27 \times 0.985 \times 0.016546 = 0.1836$ gram. Hence the impurity of the rubidium bromide was 2.7 per cent.

The rubidium sulphate was recrystallized three times. Five cubic centimeter portions of the stock solution were taken, evaporated and dried to constant weight. The samples weighed 0.1807 gram. This material was dissolved and precipitated with $BaCl_2$. The precipitate, after standing on the steam bath for twenty-four hours, was filtered off, washed and ignited to constant weight. The $BaSO_4$ weighed 0.1568 gram. The theoretical weight was $(267.06 : 233.46 :: 0.1807 : X)$ 0.1579 gram. Hence the impurity of the salt was 0.7 per cent. This is given in detail because the writer feels that physiologists generally do not realize the importance of having pure salts to start with.

The salts most extensively studied were the chlorides of sodium, calcium, rubidium and potassium. Fewer observations were made on sodium and rubidium sulphates and sodium and rubidium bromides. The sulphates of sodium and rubidium and the chloride of calcium were

used in twelfth-molar concentration, but all others were used in an eighth-molar concentration, unless otherwise stated. Assuming that salts composed of a monovalent cation and a monovalent anion dissociate into two ions, and those composed of either a divalent cation or a divalent anion dissociate into three ions (as $CaCl_2$ or Na_2SO_4) an eighth-molar solution of the former is approximately isotonic with a twelfth-molar solution of the latter. The solutions must be isotonic rather than equimolecular, for work on nerve.

In the early period of the work records were kept of the muscular twitchings, but these were discontinued after a time, since they gave no additional information. The results of a large number of experiments were averaged. In spite of the current opinion that there is nothing constant about nerve work, the writer believes that a fair degree of constancy may be obtained if reasonable precautions are taken.

RESULTS

1. Isotonic salt solutions

Sodium salts. With $\frac{M}{8}$ sodium chloride the latent period was two to three hours, and the period of contractions lasted about three hours. The contractions occurred as single twitches, and relaxation followed each contraction, with short periods of inactivity between the successive twitches. The irritability dropped considerably at first, then increased again, before the final fall. Fifty-two experiments were done for the three-hour period. As these were done at the University of Chicago, they were tested by the small induction coil, which was arranged to read at a maximum of only 21.4 cm. between the coils. Of course, no decrease in irritability was shown by this coil, so a straight line may represent the results, as shown by curve A, figure 1.

Quite a different picture is obtained when a larger coil is used. The coil used for the experiments carried out at the University of Minnesota was arranged to allow a maximum distance of 75 cm. between the coils. Twenty-five experiments were carried out with this coil, and table 1 shows the results for a period of twenty-two hours:

TABLE 1

A	0	½	1	2	3	5	7	8	9	13	22
B	63.3	31.8	24.7	27.6	39.4	43.9	61.7	40.5	39.1	31.7	12.3
C	68.0	62.5	26.5	33.5	68.0	73.0	71.0	72.0	75.0	39.2	31.0
D	57.5	22.0	21.0	20.5	15.0	13.5	45.7	8.3	7.5	22.7	5.0

As it is impossible to give all the readings for all the nerves, only the average, the maximum and the minimum readings are given in the table.

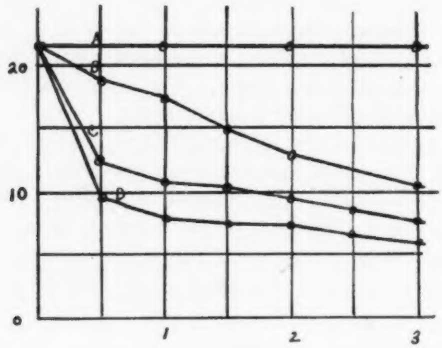

Fig. 1. A = $\frac{M}{8}$ NaCl; B = $\frac{M}{12}$ $CaCl_2$, table 4; C = $\frac{M}{8}$ KCl, table 6; D = $\frac{M}{8}$ RbCl, table 8. Abscissae—time in hours. Ordinates—distance in cms. between coils.

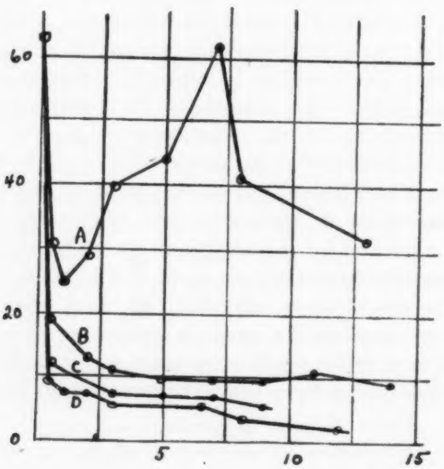

Fig. 2. A = $\frac{M}{8}$ NaCl, table 1; B = $\frac{M}{12}$ $CaCl_2$, table 5; C = $\frac{M}{8}$ KCl, table 7; D = $\frac{M}{8}$ RbCl, table 9.

A indicates the time in hours; B, the average readings of the twenty-five experiments; C, the maximum reading of the nerve showing the greatest irritability; D, the minimum reading of the nerve showing the least irritability. The extremes are variable, as shown by the table, but it must be borne in mind that the majority of the nerves were near the average degree of irritability. Of the twenty-five nerves, two had become non-irritable within twenty-two hours. Curve A, figure 2, indicates the results obtained for the longer period. The abscissae represent the time in minutes or in hours, as specified, and the ordinates indicate the distance in centimeters between the primary and secondary coils.

With $\frac{M}{8}$ sodium bromide the stimulation was less than with $\frac{M}{8}$ sodium chloride. No experiments with sodium bromide were done on the large coil, but the average for those done on the small coil is shown in table 2.

TABLE 2

	TIME								
	0	$\frac{1}{2}$	1	2	3	4	5	7	12
Average............	21.4	21.4	21.4	21.4	21.4	21.4	19.6	17.6	12.8
Maximum..........	21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4
Minimum...........	21.4	21.4	21.4	21.4	21.4	21.4	5.7	5.1	2.2

Only nine experiments were carried out with this salt. No comparisons can be made with the other sodium salts respecting the original drop in irritability, since the small coil did not register this. The bromide is evidently more toxic than the chloride, as shown in curve B, figure 3.

Sodium sulphate in $\frac{M}{12}$ concentration was more toxic than either the chloride or the bromide. The latent period of stimulation was from ten to twenty minutes, then prolonged low tetanus continued from one to three hours. The decrease in irritability was more rapid and greater than in the other sodium salts. The results of thirty-two experiments with the small coil are shown in table 3.

The greater toxicity of the sulphate is believed to be due to the sulphate ion, rather than to the higher sodium ion concentration. In the Hofmeister series sulphate is more effective than chloride, in many physical systems, so we expect it to behave as it does in physiological systems. Its toxicity is shown in curve C, figure 3.

TABLE 3

	TIME									
	0	½	1	1½	2	2½	3	5	7	12
Average	21.4	20.9	20.9	20.5	19.4	18.2	15.1	7.6	5.2	2.7
Maximum	21.4	21.4	21.4	21.4	21.4	21.4	21.4	20.0	19.2	14.5
Minimum	21.4	8.5	7.7	7.0	5.8	1.8	1.0	1.0	1.0	1.0

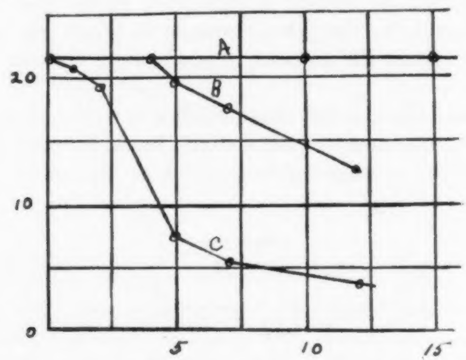

Fig. 3. A = $\frac{M}{8}$ NaCl; B = $\frac{M}{8}$ NaBr, table 2; C = $\frac{M}{12}$ Na_2SO_4, table 3

Calcium salts. The chloride was the only calcium salt used. In $\frac{M}{12}$ concentration it did not stimulate the nerve, but it did produce a medium decrease in irritability. Mathews (28) states that sodium salts are necessary for the maintenance of irritability of the nerve. The author found the nerves still irritable after being immersed in calcium chloride for sixteen hours. Calcium chloride occupies a position between sodium on the one hand, and rubidium and potassium on the other, in respect to its depressing effect. Sixty-six experiments were carried out with the small coil for three hour periods. The results are shown in table 4, also in curve B, figure 1.

TABLE 4

	TIME						
	0	50	60	90	120	150	180
Average	21.4	18.8	17.1	14.8	12.6	11.7	10.4
Maximum	21.4	21.4	21.4	21.2	21.4	21.4	18.8
Minimum	21.4	7.3	6.0	6.3	6.0	3.0	3.0

Twenty experiments were carried out with the large coil for long periods. The results are shown in table 5, and in curve B, figure 2.

TABLE 5

	TIME													
	0	½	1	2	3	4	5	7	9	10	11	12	14	18
Average	63.3	18.8	17.1	12.6	10.4	9.7	9.6	9.7	9.4	10.8	10.5	10.3	8.9	7.3
Maximum	75.0	21.4	21.4	21.4	18.8	18.1	15.6	9.0	17.1	16.4	15.9	15.0	14.0	14.0
Minimum	59.0	7.3	6.0	6.0	3.0	3.6	2.9	2.5	3.0	3.0	3.0	3.0	2.0	1.0

Thirteen out of twenty were still living at the end of fourteen hours, and three out of six were living at the end of eighteen hours.

Potassium salts. The chloride was the only potassium salt studied. An $\frac{M}{8}$ solution of potassium chloride was found to be a stimulant of the nerve, contrary to the observation made by Mathews (1). Eighty-seven experiments were carried out on this salt alone, and in about 80 per cent of the cases, stimulation occurred. The latent period was from ten seconds to one minute, and the contractions continued from two to four minutes, rarely longer. This stimulation may have been overlooked by previous investigators, but that it was due to the potassium chloride is shown by the fact that it occurred with no other salt. The decrease in irritability was rapid, and the results certainly show that rubidium and potassium chloride are similar in their toxicity effects (consult curves C and D, figs. 1 and 2).

Table 6 shows the results for three-hour periods, of eighty-seven experiments.

TABLE 6

	TIME						
	0	30	60	90	120	150	180
Average	21.4	12.3	10.7	10.2	9.4	8.4	7.4
Maximum	21.4	21.4	20.2	21.2	19.8	18.2	15.4
Minimum	21.4	5.8	2.5	3.0	3.0	2.5	1.1

Only twenty experiments were carried out on the large coil for longer periods. The results are shown in table 7.

TABLE 7

	TIME									
	0	½	1	2	3	4	5	6	7	8
Average	63.3	12.3	10.7	9.4	7.4	7.1	7.5	7.4	6.4	5.3
Maximum	75.0	21.4	20.2	19.8	15.4	13.0	12.0	9.8	8.6	7.4
Minimum	59.5	5.8	2.5	3.0	1.1	3.0	3.0	5.2	4.0	3.3

Rubidium salts. Rubidium chloride is undoubtedly a strong stimulant for nerve fiber. The latent period was found to be from ten seconds to two minutes. Twitching began, followed soon by tetanus, which continued from ten to twelve minutes. After a few single twitches the muscle relaxed and remained quiet during the remainder of the experiment. A rapid decrease in irritability was found, but a complete loss of irritability did not occur, even in twelve hours. This observation does not confirm that of Mathews, but may be attributed to a difference in technique.

Table 8 shows the results of thirty-eight experiments, on the small coil, for three hour periods.

TABLE 8
Curve D, fig. 1

	TIME						
	0	30	60	90	120	150	180
Average	21.4	9.9	7.8	7.4	7.1	6.1	5.8
Maximum	21.4	16.0	16.5	16.2	16.2	14.0	14.0
Minimum	21.4	5.5	5.2	3.0	2.5	2.0	1.0

Twenty experiments were carried out for long periods on the large coil. The results are shown in table 9, and likewise in curve D, figure 2.

TABLE 9

	TIME								
	0	½	1	2	3	4	6	8	12
Average	63.3	9.9	7.8	7.1	5.8	4.7	5.0	3.4	1.7
Maximum	75.0	16.0	16.5	16.2	14.0	6.1	8.3	7.6	8.0
Minimum	57.5	5.5	5.2	2.5	1.0	3.0	2.0	0.5	0.4

Rubidium bromide in $\frac{M}{8}$ concentration is less stimulating than rubidium chloride. It always stimulates in an $\frac{M}{4}$ solution, and occasionally in an $\frac{M}{8}$ solution. The decrease in irritability was less than with

the chloride. The following table shows the results of fifteen experiments, conducted with the small coil, for long periods.

TABLE 10

Curve B, fig. 4

	TIME										
	0	½	1	1½	2	2½	3	5	8	10	12
Average..........	21.4	9.6	9.4	8.2	7.5	7.2	6.6	5.6	5.4	5.6	2.5
Maximum........	21.4	13.3	13.0	11.0	10.2	10.4	9.4	8.5	9.5	9.2	5.6
Minimum.........	21.4	6.8	6.5	5.2	3.8	5.2	4.4	2.6	1.7	2.5	0.8

Rubidium sulphate is a stronger stimulant than the chloride, and the toxicity is greater. The action of the rubidium sulphate bears a relation to the actions of rubidium chloride and rubidium bromide similar to the relation between sodium sulphate and the chloride and bromide. Table 11 gives the average for eight experiments.

TABLE 11

Curve C, fig. 4

	TIME									
	0	½	1	1½	2	2½	3	6	7	8
Average................	21.4	10.2	8.5	6.3	6.1	4.9	4.3	4.4	3.2	2.4
Maximum..............	21.4	18.7	17.1	13.8	10.3	9.4	7.3	5.0	4.2	3.6
Minimum..............	21.4	6.6	6.1	4.8	2.9	1.2	1.2	3.4	2.0	1.0

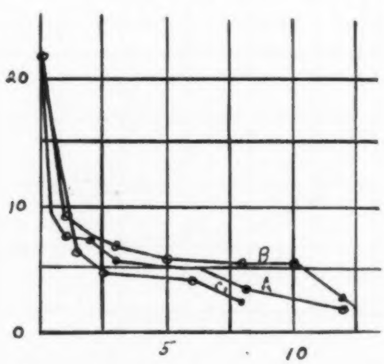

Fig. 4. A = $\frac{M}{8}$ RbCl, table 9; B = $\frac{M}{8}$ RbBr, table 10: C = $\frac{M}{12}$ Rb_2SO_4, table 11

2. Combinations of three salts

Investigations were carried out in which rubidium was used instead of potassium in Ringer's solution. The Ringer's solution used as a control contained 7 grams of sodium chloride plus 1 cc. of 2.5 M KCl plus 1 cc. of 2.5 M $CaCl_2$ per liter. The modified Ringer's solution contained the same amounts of sodium and calcium chlorides, and 1 cc. 2.5 M RbCl per liter, instead of the same amount of KCl. The following table shows the results of twenty experiments, conducted with the large coil, for long periods:

TABLE 12

Curve B, fig. 5

	TIME								
	0	½	1	1½	2	2½	3	7	18½
Average	63.3	55.8	54.8	53.5	52.7	52.7	53.1	55.0	35.9
Maximum	75.0	78.5	71.5	62.5	63.0	63.0	63.0	65.0	48.5
Minimum	45.0	45.0	45.0	45.0	44.0	44.0	44.0	13.5	13.5

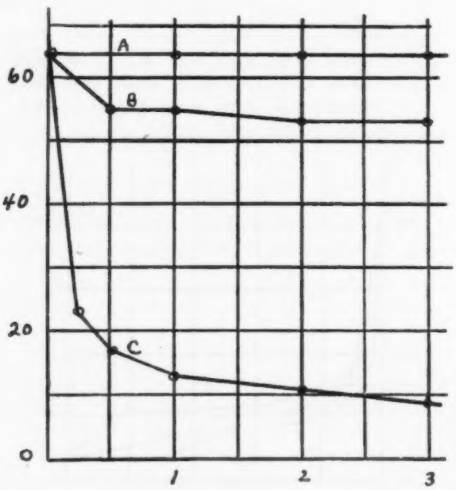

Fig. 5. A = Controls in Ringer; B = Ringer—K substituted by Rb, table 12; C = Ringer—Na substituted by Rb, table 13.

This shows that rubidium is certainly closely related to potassium, since the nerves lose very little in irritability within several hours, in a solution containing rubidium in place of potassium.

Another series of experiments was carried out in which rubidium was used instead of sodium in Ringer's solution. This solution contained 119.6 cc. of $\frac{M}{1}$ RbCl per liter, 1 cc. of 2.5 M $CaCl_2$, and 1 cc. of 2.5 M KCl. This modified Ringer was found very toxic, as shown in table 13, and again in curve C, figure 5, where the results of twenty-four experiments are given. Certainly rubidium is not similar in its action to sodium, else it could replace it in a balanced solution.

TABLE 13

	TIME							
	0	¼	½	1	1½	2	2½	3
Average	63.3	23.7	16.7	12.3	11.7	10.2	9.7	8.4
Maximum	75.0	50.0	30.0	23.5	22.0	19.0	18.0	16.0
Minimum	57.5	10.5	6.0	6.0	5.5	5.0	5.5	5.5

Curve A, figure 5, represents the controls in Ringer's solution. As these were run with daily observations a large number was obtained, but the curve shown may be considered to represent twenty. With frogs in good condition there was seldom any loss in irritability for twenty hours, as before stated. From these experiments alone, rubidium is shown to be most similar to potassium in its physiological behavior.

3. *Hypotonic solutions*

A series of experiments was performed with varying concentrations of rubidium salts. In one series a concentration of twentieth or fortieth molecular was used, knowing that the solution was hypotonic. In the other series a similar quantity of rubidium salt was used, but a final osmotic pressure equivalent to an eight-molar solution was obtained by the addition of the proper amount of saccharose. The results for $\frac{M}{20}$ RbCl in saccharose are shown in table 14 and in curve A, figure 6. Twenty experiments were performed.

TABLE 14

	TIME						
	0	30	60	90	120	150	180
Average	21.4	19.9	18.7	16.3	14.3	12.4	11.1
Maximum	21.4	21.4	21.4	21.4	21.4	21.4	21.4
Minimum	21.4	11.0	12.0	9.4	8.4	8.0	6.8

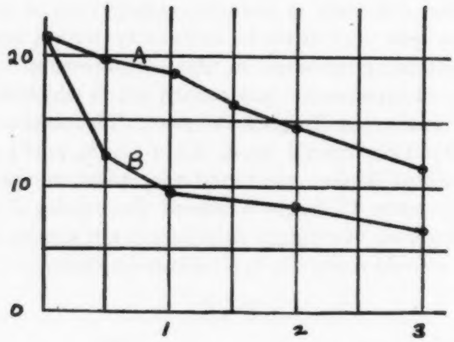

Fig. 6. A = $\frac{M}{20}$ RbCl in sacc., table 14; B = $\frac{M}{20}$ RbCl in H_2O, table 15

Eight experiments were carried out with $\frac{M}{20}$ RbCl in water, and table 15, also curve B, figure 6, show the effects of the hypotonic solution. Osmotic pressure appears to have some effect.

TABLE 15

	TIME						
	0	30	60	90	120	150	180
Average	21.4	12.1	9.3	8.4	8.1	7.8	6.5
Maximum	21.4	21.4	14.3	16.7	12.6	12.7	12.1
Minimum	21.4	6.0	6.0	3.6	3.8	3.6	1.2

The results of thirteen experiments with $\frac{M}{20}$ Rb_2SO_4 in saccharose are shown in table 16, and again in curve A, figure 7.

TABLE 16

	TIME						
	0	30	60	90	120	150	180
Average	21.4	16.9	14.7	10.7	10.3	9.1	8.8
Maximum	21.4	21.4	21.4	21.4	20.3	19.0	18.0
Minimum	21.4	9.5	8.8	8.2	6.1	4.8	1.1

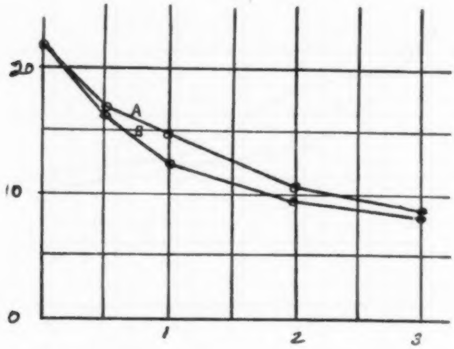

Fig. 7. A = $\frac{M}{20}$ Rb_2SO_4 in sacc., table 16; B = $\frac{M}{20}$ Rb_2SO_4 in H_2O, table 17

The results of six experiments with $\frac{M}{20}$ Rb_2SO_4 in water are shown in table 17, and in curve B, figure 7.

TABLE 17

	TIME						
	0	30	60	90	120	150	180
Average	21.4	16.2	12.3	10.6	9.3	8.7	8.2
Maximum	21.4	21.4	18.7	15.5	15.0	14.7	14.2
Minimum	21.4	11.1	9.9	8.7	5.9	6.5	5.8

This again shows a slightly higher irritability with the isotonic solution.

A very few experiments were done with $\frac{M}{40}$ Rb_2SO_4 in saccharose, the results of which are shown in table 18 and in curve A, figure 8. The corresponding nerves in $\frac{M}{40}$ Rb_2SO_4 in water gave lower results, as shown in table 19 and in curve B, figure 8.

TABLE 18

	TIME						
	0	30	60	90	120	150	180
Average	21.4	18.2	17.6	15.5	11.9	11.5	10.7
Maximum	21.4	21.4	21.4	21.4	18.2	18.8	18.1
Minimum	21.4	11.8	11.4	6.5	6.5	6.8	6.2

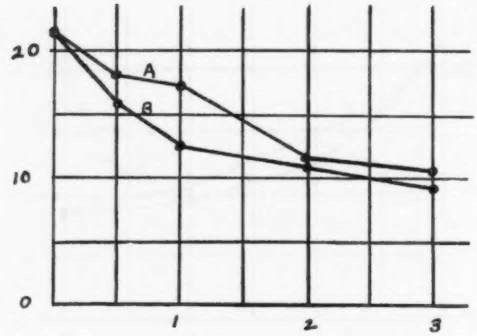

Fig. 8. A = $\frac{M}{40}$ Rb_2SO_4 in sacc., table 18; B = $\frac{M}{40}$ Rb_2SO_4 in H_2O, table 19

TABLE 19

	TIME						
	0	30	60	90	120	150	180
Average	21.4	16.0	12.6	11.7	11.3	10.3	9.1
Maximum	21.4	21.4	15.7	13.7	13.9	12.7	11.3
Minimum	21.4	10.6	8.7	8.7	9.7	8.6	7.5

This shows that the isotonic solution preserves a slightly higher irritability than the hypotonic solution. These experiments are by no means exhaustive, yet they indicate that isotonic solutions are less toxic than hypotonic, or that osmotic pressure is a possible factor in maintaining the irritability of nerves in various solutions.

4. Salt antagonisms

A series of investigations was made with combinations of two salts, for the purpose of testing the so-called antagonistic action. For these investigations 1 part of $\frac{M}{8}$ calcium chloride and 99 parts of $\frac{M}{8}$ sodium, potassium or rubidium chloride were used throughout. Twenty-one long experiments were carried out with the mixture of calcium and sodium. Undoubtedly the calcium chloride in this concentration had some antagonizing action, as shown in tables 1 and 20 and in curves A and B, figure 9.

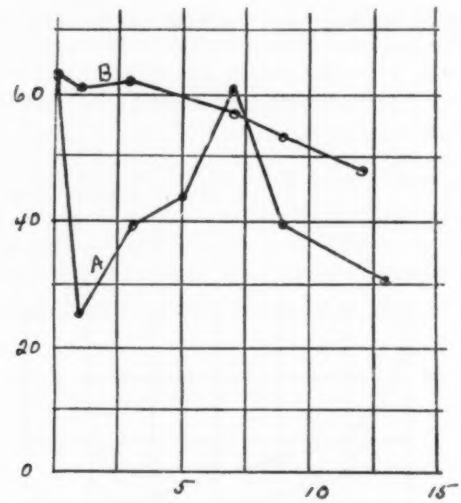

Fig. 9. A = $\frac{M}{8}$ NaCl, table 1; B = 99 parts $\frac{M}{8}$ NaCl, plus 1 part $\frac{M}{8}$ $CaCl_2$, table 20.

TABLE 20

	TIME										
	0	½	1	2	3	5	7	8	9	10	12
Average..........	63.3	60.9	60.8	61.4	62.0	59.8	57.1	56.9	53.0	49.9	48.0
Maximum........	75.0	68.5	68.5	68.5	69.0	69.0	65.4	66.0	67.0	66.5	69.5
Minimum.........	52.5	52.5	53.0	53.0	55.0	51.0	44.0	35.0	25.5	9.0	4.2

The initial fall in irritability in $\frac{M}{8}$ sodium chloride is prevented by the addition of a small amount of calcium, and even after twelve hours the nerve in the mixture is much more irritable than the one in sodium chloride alone. This surely indicates a protective action of some kind on the part of calcium.

The picture obtained by using 1 part of $\frac{M}{8}$ calcium chloride and 99 parts of $\frac{M}{8}$ potassium chloride is quite different from the above picture. Twenty-three experiments were carried out with this combination. The calcium here played a minor rôle, and its protective action was not a decided one. The results are shown in tables 6 and 21, and in curves A and B of figure 10. The decreases in irritability of the

two series were similar, the addition of calcium being slightly beneficial.

TABLE 21

	TIME				
	0	½	1	2	3
Average	63.3	14.9	13.3	10.5	9.0
Maximum	75.0	28.0	23.0	19.5	17.5
Minimum	55.0	7.5	6.7	4.0	2.5

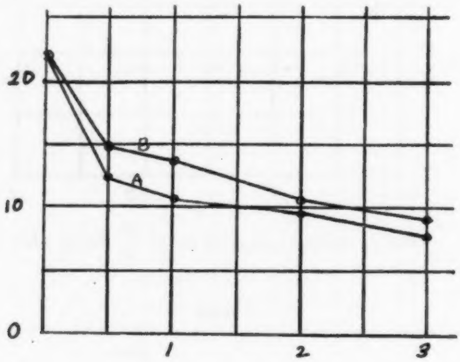

Fig. 10. A = $\frac{M}{8}$ KCl, table 6; B = 99 parts $\frac{M}{8}$ KCl plus 1 part $\frac{M}{8}$ $CaCl_2$, table 21.

Twenty-five experiments were carried out with a similar mixture of calcium and rubidium chlorides. The results were much like those obtained with the mixture of calcium and potassium chlorides. The calcium showed a slight protective action. The results are shown in tables 8 and 22 and in curves A and B of figure 11.

TABLE 22

	TIME				
	0	½	1	2	3
Average	63.3	13.1	10.8	9.3	7.9
Maximum	75.0	21.0	20.0	18.5	17.0
Minimum	55.0	5.0	4.0	2.5	2.0

It will be noticed that rubidium and potassium behave similarly in respect to the effects obtained when these are combined with a small amount of calcium. Neither is antagonized to a great extent, while in the case of sodium a decided antagonism exists.

The question of the part played by the radio-activity of rubidium has been considered by some authors. Henriot (26) states that rubidium emits a radiation giving a current of 3.64×10^{-13} amp. per sq. cm. of surface of rubidium sulphate, while in the same circumstance the radiation of potassium is only 2.74×10^{-13} amp. The rays are more intense and more penetrating than those of potassium. The radio-activities of the salts of potassium and rubidium probably serve to

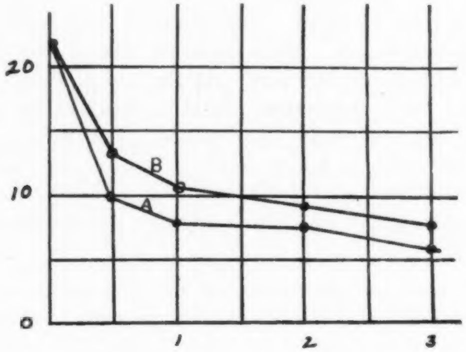

Fig. 11. A = $\frac{M}{8}$ RbCl, table 8; B = 99 parts $\frac{M}{8}$ RbCl plus 1 part $\frac{M}{8}$ $CaCl_2$, table 22.

differentiate them from the salts of sodium and calcium, in physiological effects, but facilities are not at hand for further investigation in this direction.

5. *Additional observations*

It appeared highly desirable to substantiate the physiological effects obtained above by results on non-living systems. A minor study of the comparative effects of sodium, potassium, and rubidium salts on the precipitation of lecithin and kephalin emulsions was carried out. Since the myelin sheaths of nerve fibers are composed largely of lecithin and kephalin and since the sodium and potassium contents vary considerably in lecithin and kephalin (27), it was supposed that

there would be a difference in the concentrations of the two cations required to precipitate emulsions. The lecithin and kephalin preparations used were made by the writer, from spinal cord of beef. On analysis, the lecithin yielded 1.74 per cent of N and 2. 7 per cent of P. The kephalin gave 1.92 per cent of N and 3.32 per cent of P. A small quantity (0.75 gram) was weighed out, soaked in water over night, and placed in the shaker for two and one-half or three hours, then made up to 250 cc., thus giving a 0.3 per cent emulsion. One cubic centimeter of the emulsion, a varying quantity of the salt solution and sufficient redistilled water to make a total volume of 10 cc., were measured off in each case.

Test tubes of 20 cc. capacity were used, into which the solutions were measured from burettes. The emulsion and water were mixed first, then the salt added. After thorough mixing the tubes were set aside in a cold place for 24 hours. At the end of this time the tubes were examined for precipitates. By this method the precipitation limit for each salt was readily determined. For an example, 1 cc. of 0.3 per cent emulsion + 4.5 cc. H_2O + 4.5 cc. $\frac{M}{100}$ $CaCl_2$ contained 0.03 per cent emulsion and 0.0045 M $CaCl_2$. The results, or precipitation limits, obtained by the above method, are shown in table 23.

TABLE 23

SALT	LECITHIN	KEPHALIN
$CaCl_2$	0.004–0.0035M	0.003–0.0025M
NaCl	0.250–0.225M	0.275–0.250M
KCl	0.350–0.325M	0.375–0.350M
RbCl	0.350–0.325M	0.350–0.325M
Na_2SO_4	0.150–0.125M	0.200–0.175M
NaBr	0.300–0.275M	0.300–0.275M
RbBr	0.375–0.350M	0.375–0.350M

Since in kephalin the potassium greatly exceeds the sodium, and in lecithin the reverse condition exists (27), it was expected that the precipitation limits would vary accordingly, but such was not the case. Since no striking differences were apparent between the sodium salts on one hand and those of rubidium and potassium on the other, this line of experimentation was discontinued.

SUMMARY

What happens when a nerve is placed in a salt solution? Mathews (28) long ago concluded that the stimulating or depressing effects exerted by electrolytes on the nervous system depend upon the relative efficiency of anions and cations. If in a given salt the anion markedly predominates, the salt stimulates; if the cation predominates, the salt depresses. The results above agree with this, since sodium, rubidium and potassium chlorides were stimulating agents, and calcium chloride was a depressing agent. In what manner does one salt stimulate and another depress? This question is as yet unanswered.

There is undoubtedly an antagonistic action between calcium chloride and sodium chloride as shown above; Clowes (29) and Mathews both consider such an antagonism attributable to a balance between cations on one hand and anions on the other. But why is not the antagonism between calcium chloride and rubidium or potassium chloride just as marked? In Clowes' emulsion systems sodium may be replaced by potassium; this does not hold for nerve work. Rubidium and potassium behave very much alike in physiological systems, but sodium differs from them. That rubidium and potassium are alike is shown by the similar effects on the irritability of the nerve in the pure solution, by the fact that rubidium can replace potassium in Ringer's solution, and by the failure of calcium, in the concentration used, to antagonize the toxic effects of either. The rate of diffusion, the solution tension and various other factors undoubtedly enter into the effects produced on physical and physiological systems, but the subject is still shrouded in darkness.

CONCLUSIONS

As a result of measuring the comparative rate of loss of irritability, the writer considers that the observations indicate that:

1. The effects of rubidium and potassium salts on motor nerve of frog are not so widely different as has formerly been supposed. The rate of loss of irritability appears to parallel the stimulating power of the salts studied (excepting calcium chloride, which does not stimulate, but does cause a loss of irritability).

2. An isotonic potassium chloride solution, $\frac{M}{8}$, does stimulate motor nerve of frog in at least 80 per cent of the cases.

3. Calcium chloride in isotonic solution, $\frac{M}{12}$, occupies a position between potassium and rubidium on one side and sodium on the other, in respect to its depressing effect on nerve.

4. Osmotic pressure plays a rôle, since hypotonic solutions were more toxic than isotonic solutions.

5. Rubidium is more nearly related to potassium than it is to sodium, and does not have an action on nerve peculiar to it alone.

6. Calcium chloride exerts a pronounced antagonistic effect on sodium chloride, and a scarcely perceptible one on rubidium and potassium chlorides.

7. Each salt has a specific action on nerve.

The author wishes to express her gratitude to Dr. F. C. Koch for his kindly interest in this work, the latter part of which he supervised.

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THE PRACTICABILITY OF FEEDING A SCIENTIFICALLY BALANCED RATION IN ARMY CAMPS

R. J. ANDERSON

From the Section of Food and Nutrition, Division of Sanitation, Medical Department, U. S. Army

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The proper feeding of an army or of army divisions, such as were in training in numerous camps throughout the country during the past year, presents several important problems. First of all available food supplies must be considered. Those furnished by the Subsistence Branch of the Quartermaster's Corps constitute the Garrison Ration Articles. Certain supplementary articles may be obtainable in the local markets or adjacent territory. Equally important are the matters of storage, the prevention of spoilage and the cooking of the raw food products into edible and nutritious food. With ample food supplies available, those responsible for the feeding of the army must select such combinations of food as will safeguard and maintain the health of the troops and increase their vigor. In this selection it is necessary to consider the relative proportions of protein, fat and carbohydrate, and perhaps also the acid and basic elements contained in the food, together with so-called vitamines, which should be supplied for a properly balanced diet. In addition to the above a satisfactory diet must also contain a certain amount of roughage or indigestible residue.

It is self-evident that a group of men cannot subsist upon calories alone, but upon nutritious and wholesome food containing an adequate amount of nourishment for the bodily needs of repair and supplying sufficient fuel value in addition for the performance of such work as may be required. Unless these conditions are fulfilled the men will become dissatisfied, the morale will be lowered and the efficiency of the organization will be decreased.

In ordinary life people of ample means choose their food according to taste and appetite. The selections which are made are usually sufficiently varied to furnish an adequately balanced diet. It not infrequently happens, however, among the poor and ignorant that a

thoroughly inadequate diet is either selected or thrust upon them by necessity, with resultant serious disturbances in health and vigor.

In the army the men can not choose their own diet. The food is placed before them in the mess and they may either eat it or leave it. It is therefore of the utmost importance that the food supplied be properly and wisely selected and also that it be prepared so as to preserve or increase its nutritious and appetizing qualities.

In considering what constitutes a balanced diet we must bear in mind what was said above, that men do not live on calories alone. Frequent changes of menu and as great a variety of food as possible are not only desirable but necessary. It would be very easy to supply an adequate number of calories to any group of men if but little attention were given to variety, but it requires more care, experience and planning to furnish the necessary number of calories in a well-balanced diet upon which men can subsist to advantage for long periods.

All of the troops in the new armies in training camps in this country during the recent emergency were fed on the basis of the Garrison Ration and all of the messes enjoyed the privilege of "Ration Savings." In addition to the Garrison Ration articles extra-ration food supplies, such as fresh vegetables, fruits, eggs, etc., were usually purchased by the mess sergeants in the local markets and were paid for out of the ration savings. The Garrison Ration formed merely the basis upon which the cash value of the ration allowance was calculated, each organization receiving money credit for the number of men entitled to ration multiplied by the ration allowance. The money value of the ration allowance varied from month to month and from camp to camp, depending upon prevailing food prices. Against this money credit the organization drew at certain intervals such Garrison Ration articles as were needed during the month. The amount of the total food supplies thus drawn by each mess from the Quartermaster varied within rather wide limits (from about 65 to 90 per cent of the ration allowance) and it varied from camp to camp, depending upon local camp regulations as well as upon local market conditions. Under army regulations in effect April 1, 1919, all of the food used by troops must be purchased by, and supplied through, the Subsistence Branch of the Quartermaster's Corps. The ration savings privilege has been revoked, all savings reverting to the Government. However, 25 per cent of the ration allowance may be expended by the Camp Supply Officer in purchasing extra-ration articles. The success of this system will depend, of course, upon the ability of the Supply Officer to obtain

all of the articles called for and in sufficient quantity to fill the demand. Even under the old system a month seldom passed when the Subsistence, Branch was not out of certain products for a longer or a shorter period. Forced issues of various food products which were overstocked and therefore likely to spoil were also not uncommon. On the whole however, the new system has much to commend it. The purchase of all food supplies is centralized in one office, which should lead to much desired efficiency as well as economy in feeding the army. The outstanding disadvantage is that perishables can usually be purchased most advantageously on an opportunistic basis.

Under army regulations the company commander is responsible for the proper feeding of the men. In actual practice, however, it was frequently found that this duty was left largely, if not entirely, in the hands of the mess sergeants. Occasionally, however, mess officers and company commanders took a lively interest in the mess conditions of the men. In such cases results were more satisfactory than when the mess sergeants were largely left to their own devices. Often one could tell by mere inspection of the messes whether the commanding officers gave them their personal attention.

As has been indicated above, the amount of food consumed and the proportion of the different nutrients in the diet varied greatly in different messes in a camp. It could hardly be otherwise when we consider the enormous expansion of the army within a few months and the lack of training of the new soldiers in matters pertaining to dietetics and cooking. Mess sergeants and cooks frequently were "made" through necessity by orders of the company commanders. It is not to be wondered at, then, that many of the messes were run on a hit-or-miss plan, so far as a successful diet was concerned. Even after the mess force had had several months' experience it was not unusual to find that the average food consumption varied by 1000 or 1500 calories per man per day in adjacent companies in the same regiment. Good cooking and high food consumption appeared to stand in direct relation.

The activities of the Schools for Cooks and Bakers naturally helped to improve matters somewhat in the long run. The commanding officers of these schools were zealous and industrious but their knowledge of dietetics was very limited. Their instruction in mess accounting, on the other hand, was adequate. On the whole these schools succeeded in working marked improvements in mess conditions.

No matter how carefully the food material is selected and the menus calculated, a successful diet can not be maintained unless provision

is made for the proper preparation and cooking of the food. The finest raw material may be ruined by poor cooks. There is, therefore, urgent need to continue schools for cooks and bakers in the army. In order to turn out competent workmen, however, it will be necessary to give the students more thorough instruction in the art of cooking than was generally given in the schools during the past year. Many of the so-called graduate cooks who were turned out were fairly well instructed in the duties of the kitchen police, but the number who actually knew how to cook food was unfortunately small.

Personal observation in several camps during the past year showed plainly the need of a more centralized and effective control over mess conditions than existed at that time. From the standpoint of efficiency, dietetic as well as financial, the practically independent operation of some 200 to 250 messes in a camp cannot be considered successful. Some one with sufficient authority should have sufficient general supervision over mess conditions to insure that adequate variety of food be provided. The making of menus for the different organizations should also be supervised in order to insure the proper combination of food-stuffs in the diet. In the past the menus were frequently made out by the mess sergeants one day at a time and the foods thus supplied depended largely upon what was on hand or on what could be immediately obtained. Much better results would be secured if tentative menus were made out for a period of, say, ten days in advance; purchase could be made then in accordance with the requirement of the menus.

At the present time we possess sufficient knowledge regarding the composition of raw food material to calculate in advance any desired diet. We can also provide adequate variety of fresh vegetables and fruits, which will supply sufficient roughage and necessary basic elements as well as vitamines. Some of the latter should undoubtedly also be furnished in the form of fresh butter.

It may remain an open question just how much food should be furnished to each man, but the aim might well be to provide on an average about 3600 calories (net) per day for men doing moderately hard work. Some men will consume more and others less, depending upon bodily condition and appetite. Careful consideration should be given to the proportion of protein, fat and carbohydrate contained in the diet. The arbitrary selection of a standard may be of doubtful wisdom. On the other hand, standards itemized by means of statistical studies need not be taken as infallible guides. It has recently been

proposed by the Division of Food and Nutrition to aim at furnishing the following balance: Protein, 12.5 per cent, a quantity known to be adequate; fat, 25 per cent, the amount being intentionally restricted on economic grounds, and carbohydrate 62.5 per cent. Before definitely selecting any standard balance for the army it might be advisable to conduct careful experiments over relatively long periods of time in order to determine what diets actually give the most satisfaction to the men and which, from a physiological as well as an economical basis, are the most desirable. A diet containing only 25 per cent of fat might be less satisfying than one of higher content. Besides, if a reasonable amount of fresh butter is provided it is difficult to keep the fat content under 30 per cent.

In this connection it is interesting to note that all officers' messes, cadets' messes in aviation fields and student officers' messes in Camp Greenleaf, in which dietary studies were made, supplied 40 per cent or more of the total calories as fat. These messes appeared to furnish a diet which corresponded more closely to the usual civilian or family fare than was furnished to enlisted men. A considerable part of the fat in these officers' messes was derived from the butter which was used according to taste at the table. Enlisted men received, as a rule, very little butter. Food which is well cooked and which contains the higher percentage of fat is undoubtedly the most appetizing and satisfying.

We believe that it would be for the interest and welfare of the army if some officer trained in the science of nutrition and in practical dietetics were connected with each camp or army division. The officers selected for this purpose should be men of thorough practical training in the army and possessing, in addition, full knowledge of the composition of food and the science of nutrition. They should be particularly well acquainted with the practical side of nutrition and the problems involved in feeding large groups of men. An effort has been made in recent months to fill this want by appointing nutrition officers to serve in camps in this country. If nutrition officers are to form a permanent addition to our new army, men of the qualifications mentioned above should be selected. They should be at least coördinate in rank with division sanitary inspectors. Nutrition officers of subordinate rank will have a limited field of usefulness and they will with difficulty be able to accomplish much in the way of fundamental improvements.

Unless matters pertaining to nutrition be placed under the super-

vision and control of men thoroughly qualified on both the theoretical and the practical sides, one may well doubt the practicability of feeding a scientifically balanced ration in army camps. The only alternative would be to maintain a separate Department of Nutrition or Alimentation in connection with the War Department in Washington, with subordinate officers in the camps who could carry out orders from the Washington office.

In connection with the feeding of a balanced ration in view of the new system of supplying all food through the Subsistence Branch, one might suggest in the interest of good nutrition as well as to aid the camp supply officer, that a uniform menu be adopted for the whole camp. This should be done, however, only under the direction of competent authority for it is realized that a uniform menu, unless carefully prepared and supervised, might lead to very unfavorable conditions and a stereotyped form of diet. The menu should be made out from ten to fifteen days in advance in order to give the supply officer an opportunity to secure the necessary raw material. Unless some such scheme is adopted the men will have to subsist upon such food supplies as are available at the subsistence store from day to day. The menus should specify the amount in pounds of the different foodstuffs to be actually used each meal for a given number of men. When this is done, having due regard to the composition of the food material, a diet of any desired composition or balance can be provided. In this way a scientifically balanced ration can be furnished an entire camp almost as easily as for a squad of men in an investigational laboratory.

The results of the dietary studies in army messes made by Survey Parties of the Section of Food and Nutrition, to which reference has already been made, showed that numerous nutritional errors were committed which could easily be corrected if proper supervision over mess conditions were maintained. For example, we reproduce below the result of two dietary studies made early last fall. One mess consumed on an average the following quantities per man per day:

	GRAMS	PERCENTAGE OF DISTRIBUTION OF CALORIES
Protein	85	12
Fat	59	20
Carbohydrate	472	68

Total calories about 2830.

In an adjoining organization in the same camp and at the same time of the year where the men did less hard work, the following amounts were consumed:

	GRAMS	PERCENTAGE OF DISTRIBUTION OF CALORIES
Protein	131	13
Fat	145	33
Carbohydrates	540	54

Total calories about 4100.

Both of the above messes were well managed and the mess sergeants were above average ability and they had had considerable experience. In the latter mess the men were receiving more food than they required for the very light work which they were doing. In the former the men were decidedly underfed. But the men in both organizations were under the impression that they were well fed. In the first mess liberal quantities of cabbage, sauerkraut, onions, turnips and potatoes were supplied, which made up a large bulk of low fuel value. This is not an isolated instance but many messes were studied in which considerable degrees of disparity were observed.

What must be especially guarded against is the excessive use of canned goods instead of fresh vegetables and fruits, and the too frequent employment of the cheaper meat products, as was frequently noticed during the past summer. When one remonstrated against this form of diet the statement was always made, "Fresh material cannot be obtained." Under the new ration system the supply officer, in handling the large demand for an entire camp, will be in a position to draw on distant markets for many articles which are not obtainable locally. This would apply particularly to vegetables, fruits and fish.

As an aid and a step in the direction of correcting dietary errors, such as those mentioned above, the adoption of a uniform menu, prepared under the supervision of an expert in nutrition, seems worthy of trial. The menu might be prepared in a conference between the nutrition officer, mess officers, mess sergeants and the supply officer. Such conferences might be held every week or ten days. This arrangement would also serve to coördinate mess consumption with available food supplies.

The hearty coöperation of the nutrition officers, mess officers and other mess personnel, and all others concerned with handling the army ration, will be required to bring about the best nutritional conditions in the army. Some one with thorough training in nutrition and practical dietetics should be authorized to supervise the diet for the whole camp in order that a scientifically and correctly balanced ration may be provided.

AVERAGE FOOD CONSUMPTION IN THE TRAINING CAMPS OF THE UNITED STATES ARMY

JOHN R. MURLIN AND F. M. HILDEBRANDT[1]

From the Section of Food and Nutrition, Division of Sanitation, Medical Department, United States Army

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One of the main objects of the Division[2] of Food and Nutrition of the Medical Department of the Army was to determine the actual food requirements of soldiers in active training. Beginning October 1, 1917, and continuing until December 1, 1918, nutritional surveys were made in 67 different camps including 49 divisional and other large concentration camps, 14 aviation fields, 3 war prison barracks, 1 recruiting station and 1 spruce production camp. Twenty-six of these camps were surveyed a second time and three of them a third time. The total of individual messes included was 458. Upon recalculation of results in the Washington office, errors were found sufficient to exclude from the final report 31 of these messes, leaving a total of 427 which could be accepted as exhibiting the necessary care and control.

From time to time as the statistical reports were received from the nutritional survey parties averages were compiled for 49, 68, 85, 143, 185, 213, 361 and finally 427 messes. Table 1 shows the average amount of food supplied, wasted and consumed on the man per day

[1] The following officers, as leaders of nutritional survey parties, contributed to the results here summarized and vouch for the accuracy of the reports: Majors Walter H. Eddy, Frank C. Gephart, Roy G. Hoskins, H. A. Mattill, J. Garfield Riley and John P. Street, all Sanitary Corps, and Majors Don R. Joseph and Caspar W. Miller, Medical Corps; Captains R. J. Anderson, N. R. Blatherwick, J. F. Brewster, Henry R. Cates, Arthur W. Dox, Paul E. Howe, F. B. Kingsbury, M. G. Mastin, Arthur W. Thomas and Drury L. Weatherhead, all Sanitary Corps; and Lieut. T. A. Wayland, Medical Corps.

[2] The Division of Food and Nutrition was established as a separate Division by authority of General Order No. 67, W. D., dated July 15, 1918. After December 2, 1918, this order was tacitly disregarded and the Division became, for convenience in administration, a section of the Division of Sanitation.

TABLE 1

Nutrients and energy consumed in training camps

	FOOD PER MAN PER DAY				CONSUMED DISTR. OF FV	WASTED	PER MAN PER DAY	
	Nutrients	Supplied	Wasted	Consumed				
					per cent	*per cent*		
Averages 49 messes	Protein, grams	139	12	127	14	9	Supplied cost	41.39 cents
	Fat, grams	129	14	115	30	11	Waste cost	3.57 cents
	Carbohydrate, grams	539	40	499	56	7	Total waste	—— pound
	Fuel value, calories	3980	343	3637	100	9	Edible waste	—— pound
Averages 68 messes	Protein, grams	139	11	128	14	8	Supplied cost	40.82 cents
	Fat, grams	127	13	114	29	10	Waste cost	3.51 cents
	Carbohydrate, grams	537	37	500	57	7	Total waste	0.82 pound
	Fuel value, calories	3853	318	3635	100	8	Edible waste	0.45 pound
Averages 85 messes	Protein, grams	139	10	129	14	7	Supplied cost	41.58 cents
	Fat, grams	130	12	118	30	9	Waste cost	3.41 cents
	Carbohydrate, grams	536	35	501	56	7	Total waste	0.82 pound
	Fuel value, calories	3977	297	3680	100	7	Edible waste	0.43 pound
Averages 143 messes	Protein, grams	139	10	129	14	7	Supplied cost	42.55 cents
	Fat, grams	132	12	120	30	9	Waste cost	3.10 cents
	Carbohydrate, grams	534	33	501	56	6	Total waste	0.85 pound
	Fuel value, calories	3987	288	3699	100	7	Edible waste	0.44 pound
Averages 185 messes	Protein, grams	138	9	129	14	7	Supplied cost	42.17 cents
	Fat, grams	130	12	118	30	9	Waste cost	2.99 cents
	Carbohydrate, grams	529	32	497	56	6	Total waste	0.82 pound
	Fuel value, calories	3944	280	3664	100	7	Edible waste	0.42 pound

Averages 213 messes	Protein, grams	138	9	129	14	7	Supplied cost 42.75 cents
	Fat, grams	133	12	121	31	9	Waste cost 3.00 cents
	Carbohydrate, grams	527	31	496	55	6	Total waste 0.83 pound
	Fuel value, calories	3963	276	3687	100	7	Edible waste 0.42 pound
Averages 361 messes	Protein, grams	133	9	124	14	7	Supplied cost 43.35 cents
	Fat, grams	130	15	115	30	12	Waste cost, 3.46 cents
	Carbohydrate, grams	513	32	481	56	6	Total waste 0.86 pound
	Fuel value, calories	3858	308	3550	100	8	Edible waste, 0.40 pound
Averages 427 messes	Protein, grams	131	9	122	14	7	Supplied cost 44.06 cents
	Fat, grams	134	11	123	31	8	Waste cost 3.20 cents
	Carbohydrate, grams	516	31	485	55	6	Total waste 0.80 pound
	Fuel value, calories	3899	266	3633	100	7	Edible waste 0.38 pound

basis; the distribution of fuel value in the food consumed; the percentage of each class of food wasted as well as the percentage of the total fuel value wasted; the cost of the food supplied per man per day; the value of the food wasted; and the average amount of total waste and edible waste, for these numbers of messes.

It will be seen that the average amount of food consumed has not changed materially with the increase in the number of messes. This is significant as showing that the number of messes surveyed is actually representative of the whole army in training. The slight decrease shown with 361 messes is due to the fact that the messes added after the average for 213 messes was made up were surveyed chiefly during the summer months. This will be referred to later in connection with the seasonal variation of food consumption.

The figure for total food consumption (3633 calories) represents an average of averages for the different messes. It was important to determine whether a weighted average would be in agreement with this result. Accordingly the food consumption per man per day for each of the 427 messes was multiplied by the average attendance and the sum of these products divided by the total number of rations daily, viz., 134,879. The average consumption by this method proved to be 3625 calories. From this result it was unnecessary to make weighted averages of food supplied and the food wasted. It was found at Camps Grant, Dodge, Pike and Devens that the average net weight after four to five months of training was 146.5 pounds. The average food consumption from the mess, therefore, may be stated as 24.6 calories per pound of body weight or 52.1 calories per kilogram.

Chart 1 exhibits a distribution curve of the food consumption for the entire 427 messes. It will be observed that this ranges from 2100 to 5700 calories per man per day. The mean of the entire number falls between 3600 and 3700, as already noted. The curve is essentially symmetrical, showing that the man per day consumption within this range is quite a matter of chance. In other words, the curve presents the features of the typical variation curve for biological phenomena. The same sort of curve representing distances of shots from the bull's eye would be obtained by firing at a small target, or again a curve representing the weights of individuals would show a similar distribution. The number of organizations, however, consuming more than 4500 calories or less than 3000 when compared with the total number is practically negligible. For all practical purposes, therefore

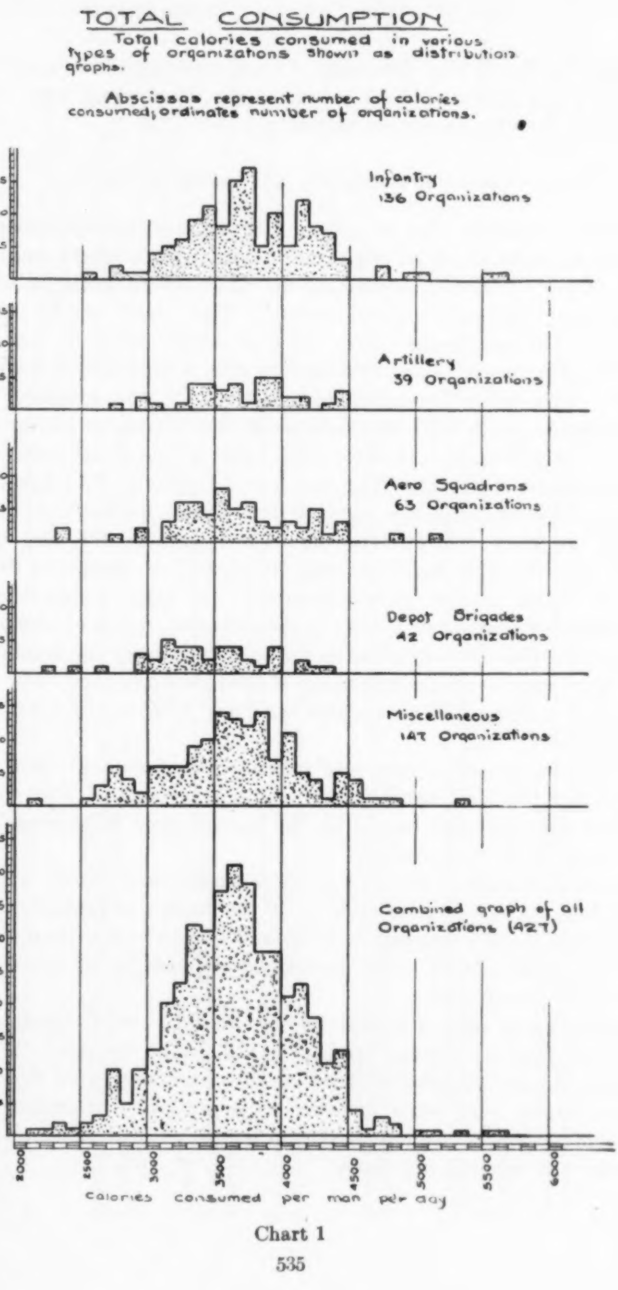

TOTAL CONSUMPTION
Total calories consumed in various types of organizations shown as distribution graphs.
Abscissas represent number of calories consumed; ordinates number of organizations.
Infantry
136 Organizations
Artillery
39 Organizations
Aero Squadrons
63 Organizations
Depot Brigades
42 Organizations
Miscellaneous
147 Organizations
Combined graph of all Organizations (427)
NUMBER OF ORGANIZATIONS
2000
2500
3000
3500
4000
4500
5000
5500
6000
Calories consumed per man per day

Chart 1

it might be stated that the range of food consumption in army messes lies between 3000 and 4500 calories with the average very close to the mean between these two extremes.

FOOD CONSUMPTION BY ORGANIZATIONS

Chart 1 exhibits also an attempt to arrange a distribution curve for the different kinds of organizations, infantry, artillery, aero squadrons, depot brigade organizations, and others grouped together under the heading "miscellaneous." The chart shows that the number of organizations of the separate kinds, with the possible exception of infantry, is not sufficient to give a satisfactory distribution curve. The actual average consumption for the artillery messes, for example, is no more representative than a number chosen at random. To practically the same extent this is true of the depot brigade organizations, including machine gun battalions, field hospital and field ambulance companies, medical detachment messes, etc.

The tendency exhibited in the infantry group, the aero squadron group and the miscellaneous group is, clearly, to duplicate the curve for the entire number of organizations. In other words, the mean, if a sufficient number of messes of the different sorts had been studied, would doubtless lie very close to that obtained from the total number. The same may be said of the range of food consumption. The number of messes outside 3000 on the one hand and 4500 on the other is quite negligible.

From the considerations just rehearsed it is evident that average figures for the food consumption in organizations of different kinds are less valuable than would be the case if some 400 messes of each sort could have been studied.

Chart 2 exhibits the average as actually determined. The only deviation worthy of note is that of the recruit organizations where the average total consumption is some 200 calories less than the grand average of all messes. The conditions responsible for this deviation will be discussed later.

Returning to table 1 it may be seen that the total consumption of nutrients for the average soldier is 122 grams protein, 123 grams fat and 485 grams carbohydrate. Before commenting on this average in comparison with other dietaries, it is necessary to consider *a*, the effect of season; *b*, the effect of the length of time in camp; and *c*, the effect of canteen purchases.

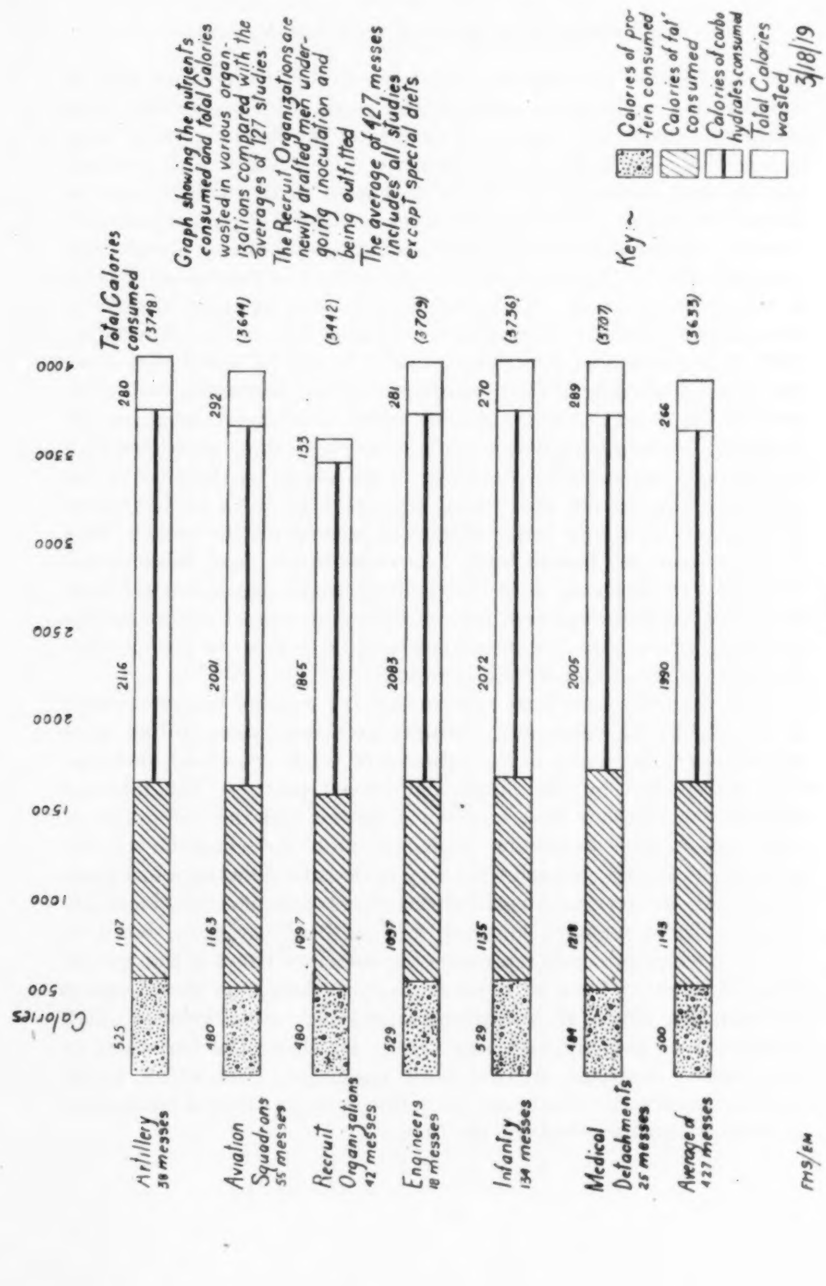

Calories
500
1000
1500
2000
2500
3000
3500
4000
Total Calories consumed
Artillery 38 messes
525
1107
2116
280
(3748)
Aviation Squadrons 55 messes
480
1163
2001
292
(3644)
Recruit Organizations 42 messes
480
1097
1865
133
(3442)
Engineers 18 messes
529
1097
2083
281
(3709)
Infantry 134 messes
529
1135
2072
270
(3736)
Medical Detachments 25 messes
484
1218
2005
289
(3707)
Averaged 427 messes
500
1143
1990
266
(3633)
Graph showing the nutrients consumed and total Calories wasted in various organizations compared with the averages of 427 studies.
The Recruit Organizations are newly drafted men undergoing inoculation and being outfitted
The average of 427 messes includes all studies except special diets
Key:-
Calories of protein consumed
Calories of fat consumed
Calories of carbohydrates consumed
Total Calories wasted
3/18/19
FMS/EM

Chart 2

THE EFFECT OF SEASON ON FOOD CONSUMPTION

It is a familiar fact that one eats more food in winter time than in summer and particularly more of the foods which stimulate heat production most, viz., meats. Few dietary studies have been made in a carefully controlled manner, however, which exhibit with certainty this seasonal variation, and so far as known to the writers, none at all made on bodies of men engaged in the same form of physical exercise. Chart 3 exhibits the average food consumption month by month from October, 1917 to December, 1918 as determined by nutritional surveys in the training camps. The number of messes included in each of these months, however, is significant only from the month of November, 1917 to the month of September, 1918. It will be noted that there is a gradual increase in food consumption from November to March, after which there is a sharp decline which continues throughout the summer. Attempts have been made to correlate these variations with the average temperatures prevailing in the camps at the time of the surveys. This has not been wholly successful, probably for the reason that there is no known factor which will account for the cooling effect of winds upon the human body. In other words, food consumption does not vary inversely with the temperature in any simple relationship, for the effect upon heat loss, and therefore upon heat production indirectly, of a windy day in summer may be as great or even greater than that of a still atmosphere in winter.

Wind velocities have been reported by the weather bureau stations in the vicinity of camps and attempts have been made to find some mathematical expression of the influence of winds upon food consumption as reported by the nutritional survey parties. The inherent error in the methods of a nutritional survey and the variability in food consumption depending probably upon the character of the cooking and service, or upon what may in short be called appetizingness of the food, are too great to exhibit the effects of the individual climatic factors. There remains, however, the seasonal variation shown in the chart which probably represents the combined effect of the various climatic factors. Thus on a priori grounds alone, one would expect a summation effect of low temperature, high wind velocity, high humidity and possibly high barometer. Of these, the variations in temperature doubtless are the most important, after which would probably come wind velocity and humidity, with the factor of barometric pressure occupying a doubtful position.

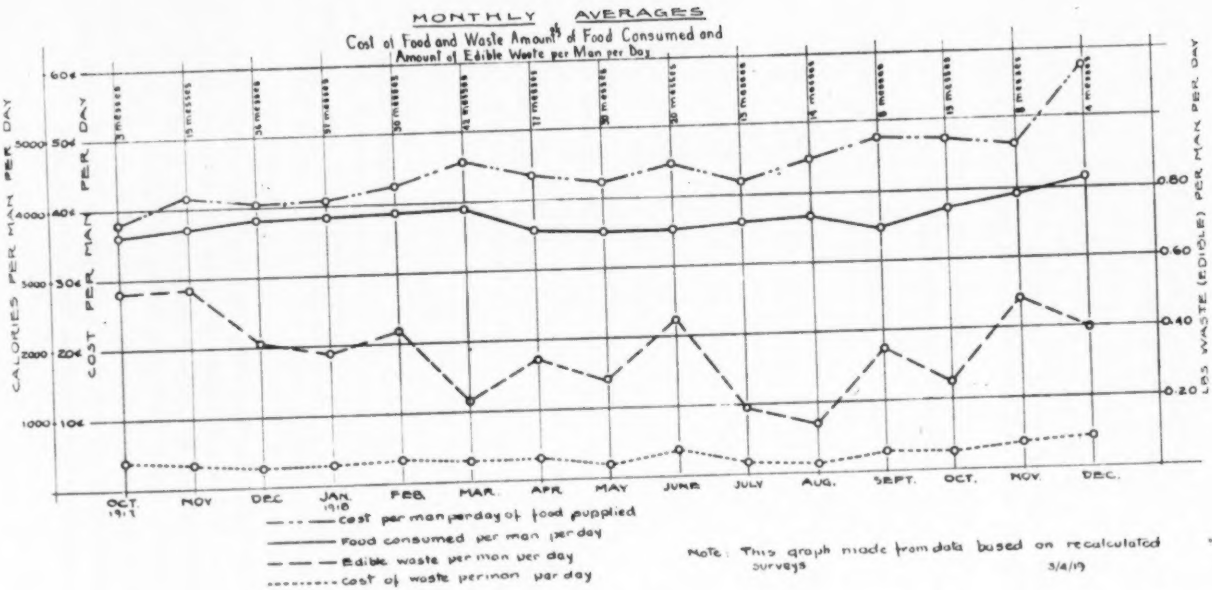

MONTHLY AVERAGES
Cost of Food and Waste Amounts of Food Consumed and Amount of Edible Waste per Man per Day
CALORIES PER MAN PER DAY
COST PER MAN PER DAY
LBS WASTE (EDIBLE) PER MAN PER DAY
60¢
5000 50¢
4000 40¢
3000 30¢
2000 20¢
1000 10¢
0.80
0.60
0.40
0.20
3 messes
15 messes
36 messes
37 messes
30 messes
43 messes
17 messes
30 messes
20 messes
15 messes
14 messes
8 messes
15 messes
8 messes
4 messes
OCT. 1917
NOV
DEC
JAN. 1918
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
Cost per man per day of food supplied
Food consumed per man per day
Edible waste per man per day
Cost of waste per man per day
Note: This graph made from data based on recalculated surveys
3/4/19

Chart 3

How much of the seasonal variations in food consumption is due to the greater stimulus of atmospheric conditions to muscular work in winter time than in summer cannot be stated. In other words, the variation shown in chart 3 is certainly not a simple effect of temperature, but is complicated still further by the indirect effect of temperature upon muscular "willingness," if one may coin such a term. Certain it is that one works with greater ease under conditions

TABLE 2

Average by months per man per day

MONTH	NUMBER OF MESSES	COST SUPPLIED	FUEL VALUE CONSUMED	EDIBLE WASTE	EDIBLE WASTE COST
				pounds	
October, 1917	3	37.72	3606	0.56	3.82
November, 1917	19	41.57	3706	0.57	3.31
December, 1917	36	40.47	3819	0.41	2.58
January, 1918	37	40.85	3827	0.38	2.64
February, 1918	30	42.41	3864	0.43	3.24
March, 1918	42	45.61	3894	0.23	2.99
April, 1918	77	43.48	3545	0.34	3.02
May, 1918	30	42.15	3514	0.28	1.85
June, 1918	20	44.86	3517	0.44	3.62
July, 1918	13	41.89	3609	0.19	1.66
August, 1918	14	44.92	3658	0.14	1.14
September, 1918	8	47.64	3487	0.35	2.85
October, 1918	13	47.33	3727	0.23	2.42
November, 1918	7	46.14	3918	0.48	3.41
December, 1918	5	57.56	4145	0.40	4.04
Total	354				
Average		44.30	3722	0.36	2.84

Above information recalculated from nutritional survey reports. All base hospitals, officers', cadets' and prisoners' messes excluded. Cost supplied is average cost of food supplied per man per day.

of low temperature, low humidity and high barometer; the effort of muscular work is less, consequently there are probably many gratuitous muscular motions in the performance of any given piece of work. The tendency to frolic amongst soldiers is highest at such a time. All of these extra motions obviously would of themselves increase the heat production quite apart from the simple cooling effect on the skin, and would correspondingly increase the desire for food.

In conclusion of this subject of seasonable variation it may be noted from chart 3 that the maximum difference between the average for the winter and the summer months is not more than 300 to 400 calories. The average soldier, weighing 146 pounds (after four or five months' training) will consume, therefore, not to exceed 400 calories more daily throughout the winter months than in the summer months. Warmer clothing, heated barracks and warm bedding each play their part in keeping down heat loss.

Chart 3 is based upon table 2. In addition to seasonal variation in food consumption this chart and table exhibit also the variation from month to month in the cost of food supplied per man per day; likewise the variation in the amount of edible waste and its value. One fact only of these additional curves will be mentioned at this place, viz., the influence of the armistice, which is apparent in the averages for food waste for the months of November and December, 1918.

EFFECT OF LENGTH OF TIME IN CAMP

A number of studies of food consumption in recruit organizations have been made. These are in agreement as showing that in the first few weeks of camp life the recruit does not consume as much food from the mess as he does after becoming thoroughly habituated to camp conditions. In illustration may be cited chart 4, which represents a study made upon a recruit company at Camp Pike during the months of July and August, 1918. For three weeks the entire company was kept together, after which the men were separated into Class "A" and Class "B" men. It will be noted that the food consumption beginning at about 2700 calories per man per day in the first week mounts successively to 3000 and 3100 in the second and third weeks respectively and by the end of the fifth week has reached the average for all messes of about 3600.

The first two weeks in camp cover the period of inoculation for typhoid and paratyphoid. This, together with the strangeness of surroundings, particularly of the mess, menus, cookery, style of service, etc., and probably lack of digestive capacity, serves to keep down food consumption and is responsible for the noticeable loss in weight the first week. The weight is promptly recovered, however, by the end of the third week.

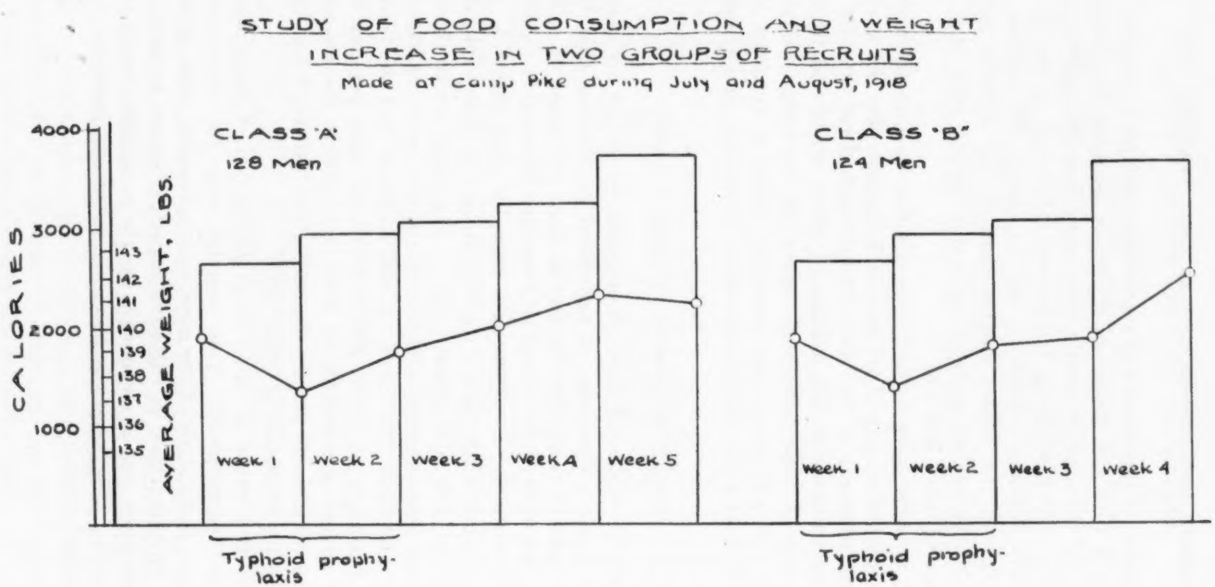

STUDY OF FOOD CONSUMPTION AND WEIGHT
INCREASE IN TWO GROUPS OF RECRUITS
Made at Camp Pike during July and August, 1918
CALORIES
4000
3000
2000
1000
AVERAGE WEIGHT, LBS.
143
142
141
140
139
138
137
136
135
CLASS 'A'
128 Men
Week 1
Week 2
Week 3
Week A
Week 5
Typhoid prophy-laxis
CLASS "B"
124 Men
Week 1
Week 2
Week 3
Week 4
Typhoid prophy-laxis

Chart 4

FOOD CONSUMPTION AT THE CANTEEN

The canteen, also called the "post exchange" or regimental "exchange," is partly a social institution and partly a supplementary mess. Regulations governing the exchange in the training camps have been on the whole very satisfactory as regards sanitation and the inspection of food materials sold therein.

It is naturally very difficult to keep a record on the man per day basis of food sold to a given organization at the exchange. The difficulty arises from several causes. In the first place, even if the organization has its own canteen, men from other organizations will make purchases there; also a single man may make purchases in the canteen for himself and a number of others. These things taken together make it difficult to pro-rate the total sales for any period. Again, the general experience of field officers has been that the post exchange is patronized much more by the recruits than by soldiers who have become habituated to the mess. Consumption may thus vary from that of the raw recruit, who in many cases will live almost entirely on candy, ice cream and cake purchased at the post exchange, to that of the old regular army man, who limits his canteen purchases largely to tobacco and toilet articles. An average of sales from a single canteen without due account of these causes would be of little value. The average of a large number of such surveys, however, may be accepted as approaching the true average consumption of food from these sources.

Altogether nutritional survey parties have reported 261 studies of food consumption from the exchange. Chart 5 represents for 27 such studies an attempt to learn whether the consumption in the exchange bears any relation to the amount of food consumed from the mess of the same organization. The canteen consumptions are arranged in the order of magnitude beginning with the largest on the left, and, for comparative purposes, the mess consumption is placed beside the canteen consumption. It will be noted that there is no definite relationship between the two. One cannot say, therefore, that soldiers purchase a large amount of food from the canteen because the mess does not supply a sufficiency of total energy. The average consumption for these 27 different canteens is 405 calories per man per day; the average for the total 261 studies is 365 calories per man per day.

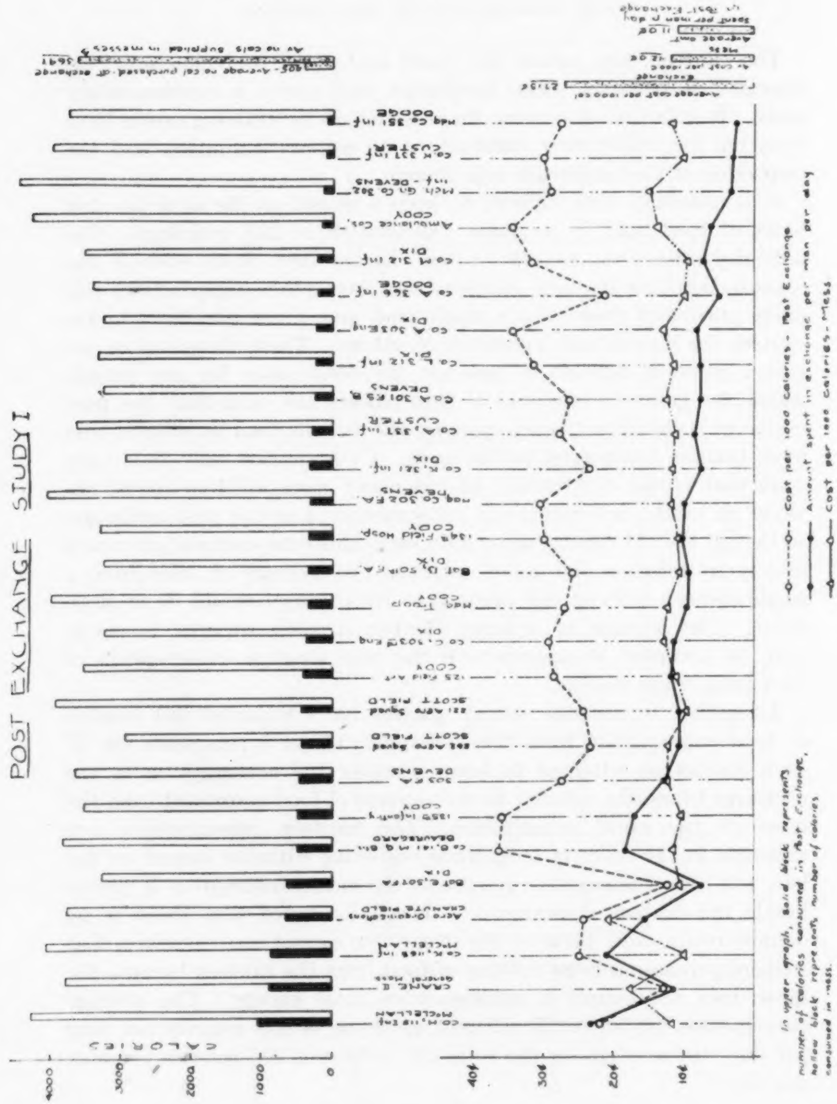

POST EXCHANGE STUDY I
CALORIES
Cost per 1000 Calories - Post Exchange
Amount spent in exchange per man per day
Cost per 1000 Calories - Mess

Chart 5

On chart 6 is shown a frequency curve representing the caloric consumption per man per day in all the exchanges studied, and a frequency curve representing the cost per thousand calories. The noteworthy feature of this study is that the frequency curve for the

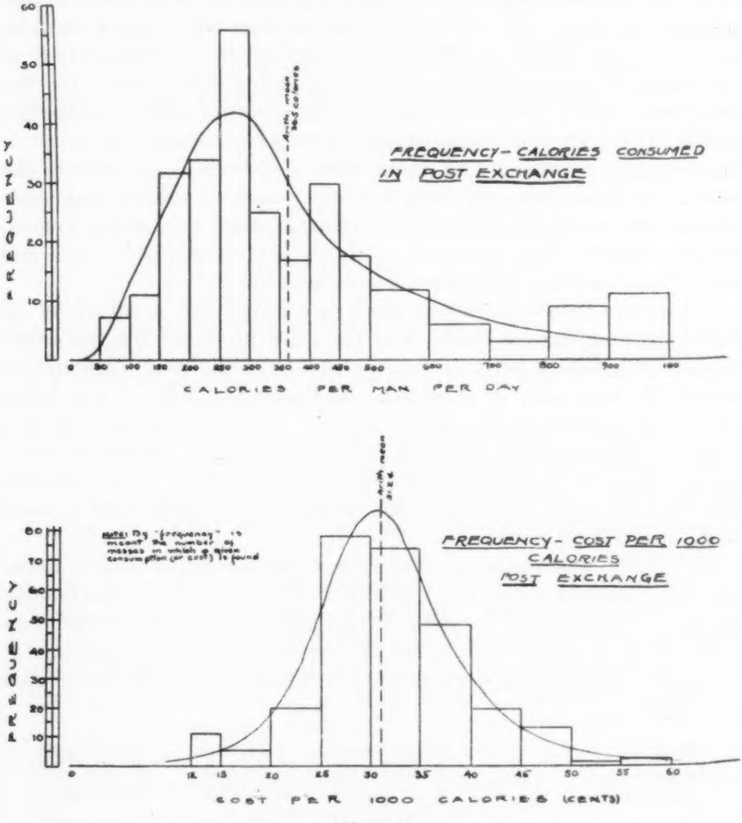


Chart 6

consumption is a skew curve, while the frequency curve of cost per thousand calories is symmetrical about the mean of all the observations. It is evident from the first curve that the amount of food purchased by the average soldier is not a mere matter of chance. To some extent the form of this curve is explained by the value in calories

of the 5, 10, 15, 20 and 25 cent purchases; to some extent also probably by the fact that in many exchanges restaurant sales were made, while in others what might be called confections only were sold.

The average consumption in the canteen does not, however, represent the average consumption outside the mess, for in many camps adjacent to cities, the soldiers had passes after the evening meal at the mess, and much supplementary nourishment was purchased in the eating houses in town. Several attempts were made by the nutritional survey parties to estimate the quantity of food consumed in this way. In some organizations men were required by order of the company commander to report what had been eaten outside the camp. In some instances there is every reason to believe that these reports were truthfully made but the terms in which they were reported, as, for example, "two pieces of candy," "a piece of pie," "ham and eggs," etc., were too indefinite for computation.

If a camp distant from any town is selected and a survey of all the camp exchanges is made, and the sales pro-rated for the entire camp population, a fairly accurate estimate of the food consumption outside the mess may be obtained. At Camp McClellan it was found possible to undertake just such a study. This camp is situated at a sufficient distance from Anniston, Alabama, to bring the consumption and purchase of food outside of camp to a low value. Also less outside food was received at this camp at the time of study than in most of the other large camps.

The study was made by Nutritional Survey Party No. 8 under the leadership of Captain H. A Mattill in March, 1918, several months before the departure of the 29th Division for overseas. The summary of this canteen survey shows that the expenditure per man per day at Camp McClellan during the week of the study was 21.9 cents, distributed as follows:

Candy	0.143 pound	6.17 cents	28 per cent
Drinks	0.921 bottle	5.05 cents	23 per cent
Cakes, cookies	0.214 pound	6.58 cents	30 per cent
Fruit	0.085 pound	1.06 cents	5 per cent
Ice cream	0.012 gallon	2.00 cents	9 per cent
Sandwiches, etc	0.044 pound	1.06 cents	5 per cent
		21.92 cents	100 per cent

The following notes quoted from the report summarize the observations of the party making the survey on the canteen situation at this camp.

The soldier buys food at the exchange probably for three reasons: (1) as a pastime and for sociability; (2) to secure sweets that take the place of alcohol, in the case of those who have been accustomed to its use; (3) because the desire for sugar, physiological or habitual, is not met by the army ration. General observation gives most weight to the last mentioned cause.

For his candy the soldier pays at the rate of 44 cents a pound; for his pastry 31 cents per pound; for his ice cream at the rate of $1.60 per gallon; and for sugar in the various drinks over $3 per pound.

Of the total expenditure 30 per cent is for cakes and box crackers, 29 per cent is for candy, 22 per cent for soft drinks, and 9 per cent for ice cream, a total of 90 per cent for sugar and starch preparations, leaving 10 per cent for fruit and miscellaneous items.

Using an average analysis for the various classes there is furnished (approximately) by

	Calories
Candy	305
Soft drinks (coca cola, etc.)	72
Fruit, 0.085 pounds	18
Cake, 0.21 pounds	124
Ice cream, 0.012 gallons	37
Miscellaneous (sandwich), 0.044 pounds	107
A total of	633

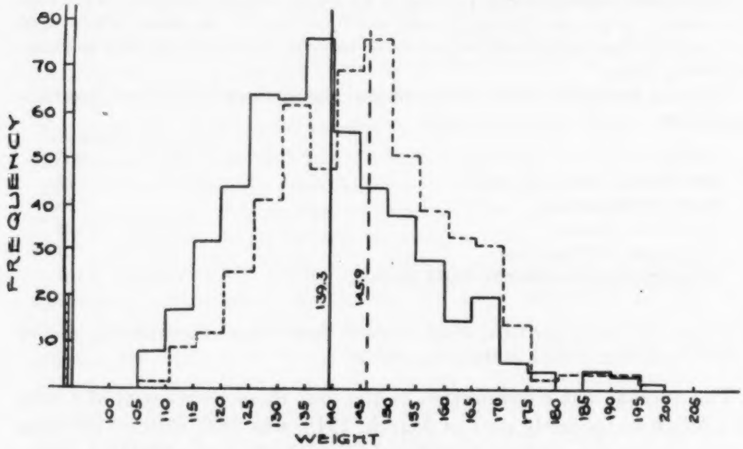
at a cost of 33 cents per 1000, which is about three times as great as the cost of a similar amount of food in the army ration.

The average net consumption in the four messes surveyed at Camp McClellan in the early part of March, 1918, was 3827 calories per man per day. Adding to this the 633 calories which represent the average consumption from all the canteens, gives the surprisingly high total of 4460 calories.

The average total consumption in the camps is found by adding to the average for all messes studied (427) the average for all canteens (261). Thus 3633 plus 365 equals 3998; the result in round numbers is 4000 calories per capita per day. Lusk[3] has estimated that it requires 4100 calories in order to maintain body weight and to supply the necessary energy for a seasoned soldier weighing 70 kilograms (154 pounds) to do a forced march of 30 miles in 10 hours carrying a pack weighing 44 pounds. Of these 1767 calories are for basal metabolism, that is, the mere maintenance of the body temperature at muscular rest. Standing alone requires 118 calories, walking 30 miles in 10 hours without pack requires 1705 calories, with pack 484 calories additional, making a total of 4704 calories for maintenance metabolism and the muscular effort.

[3] From an unpublished lecture on the *Dynamics of Nutrition*, written for the Division of Food and Nutrition as a part of the training of nutrition officers.

We have already seen that the average weight of the soldier of the first draft after four or five months' training in the camp is 146 pounds. For this weight the theoretical metabolism according to Lusk is as follows: Basal metabolism 1695, standing 113, walking 30 miles in 10 hours 1606, carrying equipment 44 pounds 484, total 3898. It may be seen therefore that the average soldier receiving 4000 calories



STUDY OF INCREASE IN WEIGHT OF 523 MEN IN THE 303 F.A., CAMP DEVENS

The weights were divided into groups differing by 5 pounds, and the number of individuals in each group counted. The group between 110-115 includes individuals weighing from 111 to 115, inclusive, the group between 115 and 120, individuals weighing from 116 to 120, inclusive, etc. In the above graph, the abscissas give the weights, the ordinates, the number of individuals in each weight group. The solid line shows the distribution at the time of enlistment, the dotted line, the distribution 5 months later. Averages are shown in a similar manner.

Chart 7

daily has energy supplied in sufficient quantity to do this maximum amount of work every 24 hours. If the work is not done, it is obvious that the soldier will take on weight and the universal testimony throughout the camps is that the recruit has gained anywhere from 3 to 9 pounds in the course of four or five months' training. At Camp Devens 523 men of the 303 Field Artillery made an average gain, which was nearly uniform for men of all sizes, of 6.6 pounds (chart 7).

It is certain, therefore, that the average food consumption of 4000 calories is sufficient for the training period. Making an average allowance of 7 per cent for waste (see table 1), a total food supply of 4280 calories would amply supply all needs, including the canteen. This, it should be remembered, covers the needs for men of all sizes and under all conditions of muscular work and climate.

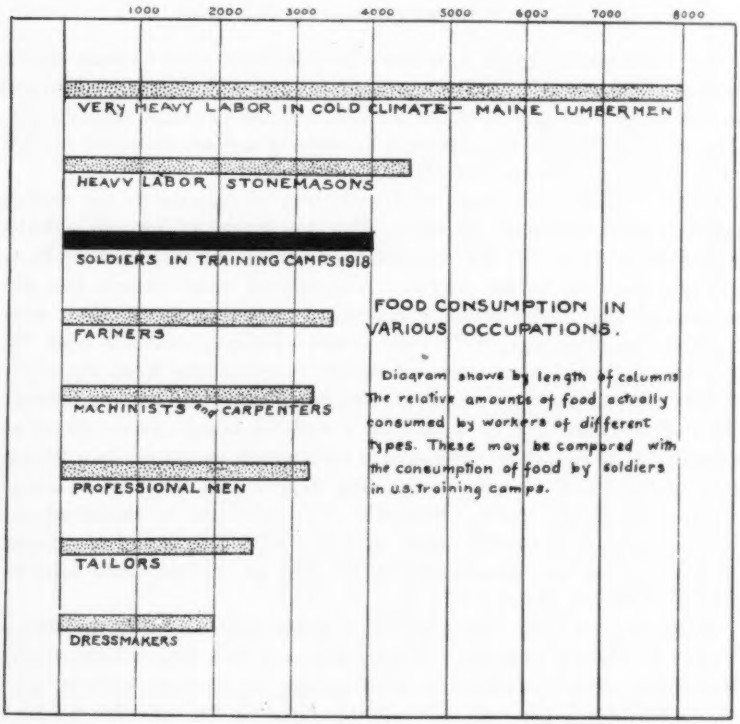


Chart 8

FOOD CONSUMPTION IN THE ARMY COMPARED WITH OTHER OCCUPATIONS

In chart 8 is shown diagrammatically the relation of average food consumption in a training camp in comparison with lumbermen, stone masons, farmers, machinists, professional men, tailors and dressmakers.

This diagram is based upon statistical observations made by well-known authorities and summarized in Lusk's *Science of Nutrition* (Second Edition, p. 348). The physical work of the soldier may be characterized as somewhat heavier than that of the American farmer, and not quite so heavy as that of a stone mason, who works steadily at lifting and hammering his materials for a period of eight hours.

DISTRIBUTION OF NUTRIENTS IN THE ARMY DIET

By reference to table 1, it may be seen that the average distribution of calories derived from protein, fat and carbohydrate consumed in the mess is 14 per cent, 31 per cent and 55 per cent respectively. The distribution for the different number of messes averaged in that table is seen to vary but little from this standard.

Chart 9 shows the range of distribution of calories to the several organic constituents of the diet. The percentage of protein calories varies from 11 to 17, fat calories from 20 to 40 and carbohydrate calories from 45 to 65 calories. Throughout these ranges the distributions are fairly symmetrical about the means. If they were perfectly symmetrical, the means would obviously coincide with the averages. Stated somewhat differently, it is obvious from the study of this chart that any given recruit cast into a camp and passing through the mill mechanically, as a ball on a roulette board, would stand an exactly equal chance of obtaining a diet which would contain 25 per cent of fat calories as one containing 37 per cent, that is, an equal distance from the mean. Similarly with reference to carbohydrate, he would stand an exactly equal chance of obtaining a diet containing 50 per cent as one containing 60 per cent of carbohydrate calories. So also with the protein.

When the canteen consumption is taken into account, the distribution is slightly changed. Examination of the report from Camp McClellan already referred to shows that the average canteen purchases contain 8 per cent protein, 16 per cent fat and 76 per cent carbohydrate. When the 365 calories are distributed according to these percentages and added to the consumption obtained in the mess, it is found that the distribution of protein, fat and carbohydrate for the total consumption is 13 per cent, 31 per cent and 56 per cent respectively. The predominance of carbohydrate in the canteen consumption serves to lower slightly the percentage of protein, to raise slightly the percentage of carbohydrate and to leave unaffected the percentage of fat.

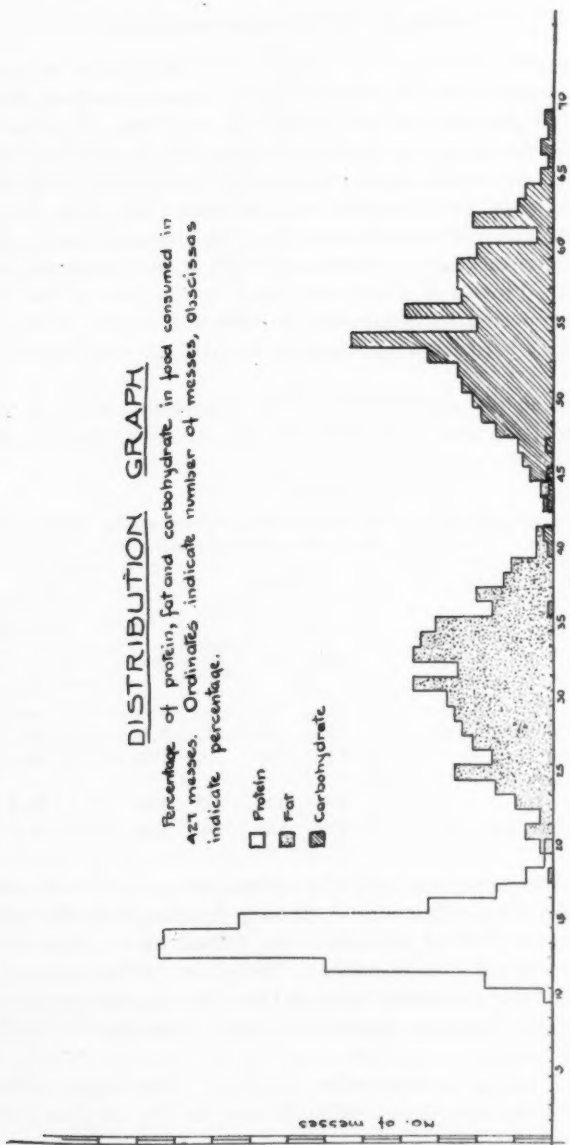

DISTRIBUTION GRAPH
Percentage of protein, fat and carbohydrate in food consumed in 427 messes. Ordinates indicate number of messes, abscissas indicate percentage.
Protein
Fat
Carbohydrate
No. of messes
— PERCENTAGES —
120
110
100
90
80
70
60
50
40
30
20
10
5
10
15
20
25
30
35
40
45
50
55
60
65
70

Chart 9

COMPARISON WITH OTHER DIETARIES

It is a matter of interest to compare this distribution of nutrients in the army diet with the distribution in certain standard diets well known in the literature of the science of nutrition. It is somewhat surprising to find that the percentage of protein is considerably lower in the diet of the soldier than in that of Voit's old ration for hard labor which has always been regarded as a moderate one from the standpoint of protein. The impression that the consumption of meat in the army training camp is excessively high is not borne out by this comparison. Protein is lower even than in the diet of the Finnish peasant as reported by Sundström in 1908 and in that of the American farmer at hard labor as estimated by Atwater some twenty years ago.

The total energy consumption of the American soldier in training approaches the Atwater standard for the American farmer at hard labor.

TABLE 3

Comparison of the soldier's diet in United States army training camps with other standard diets for hard muscular work

	GRAMS			CALORIES			
					Percentages		
	Protein	Fat	Carbohydrates	Total	Protein	Fat	Carbohydrates
Sundström (Finnish peasant)....	136	83	523	3474	16.1	22.2	61.7
Voit (hard labor)................	145	100	500	3574	16.6	26.0	57.4
United States soldier (hard training)......................	129	136	545	3998	13.2	31.6	55.8
Atwater (farmer, hard labor)....	150	125	580	4150	14.8	28.0	57.2

Likewise in comparison with the rations prescribed for the training period of the other allied armies, as may be seen from the following table, the percentage of protein in the United States Army is lower than that of the British, Canadian, French or Italian Armies. The percentage of fat consumed is lower than the amount prescribed for the British and Canadian Armies and higher than that of the French and Italian Armies.

The total energy consumption, however, shows how difficult it would be for the American soldier to live on the training ration of either of the other armies.

PERCENTAGE OF CALORIES SUPPLIED BY CHIEF COMPONENTS OF THE RATION

In chart 10 is shown the percentage of total calories supplied by each of the more important constituents of the army diet; likewise the percentage of protein calories, fat calories and carbohydrate calories furnished by each of the more important constituents. This study is based upon the first 87 messes and the first 213 messes surveyed. The importance of bread, beef, potatoes and sugar stands out prominently in a comparison of this sort. The chief difference observed between the

TABLE 4

Training rations of the different allied armies

	GRAMS			CALORIES			
					Percentages		
	Protein	Fat	Carbo-hy-drates	Total	Protein	Fat	Carbo-dy-drates
British Home ration, May, 1918..	124	136	419	3483	14.6	36.4	49.0
Canadian, July, 1918.............	107	118	344	2946	14.9	37.2	47.9
French, Normal, March 29, 1918	138	98	467	3604	15.7	25.3	59.0
Italian territorial, February 1, 1917...........................	127	38	469	2797	18.6	12.6	68.8
United States Garrison ration A. R. 1221.........................	147	174	643	4859	12.5	33.3	54.2
Consumed in United States training camps 427 messes and canteen purchases............	129	136	545	3998	13.0	31.0	56.0

two studies lies in the fact that there is in the second a considerable increase in the percentage of total energy as well as the percentage of each of the three nutrients derived from foods other than the principal staples included on the food list. In other words, from the time when the average for 87 messes was compiled to the time when the average for 213 messes was compiled, a period of two or three months, the number of different articles of food used in significant amount increased considerably. This reflects greater freedom and more intelligence on the part of the mess sergeant in purchasing food from outside sources.


TOTAL CALORIES
PROTEIN CALORIES
FAT CALORIES
CARBOHYDRATE CALORIES
CALORIE DISTRIBUTION
Showing relative importance of the most frequently used foods as sources of energy, protein, fats, and carbohydrates. Figures show amount of total energy, protein, fat, and carbohydrate furnished by individual foods and are expressed as percentages of total calories, total protein calories, total fat calories, and total carbohydrate calories respectively. The first figure and the solid block represent in the case of each food the percentage as determined from the average consumption in 213 army messes. The figure in parentheses and the hollow block show the percentage as determined from the average consumption in 87 of the 213 messes.
The 37 messes were surveyed between October 1, 1917 and February 15, 1918

Chart 10

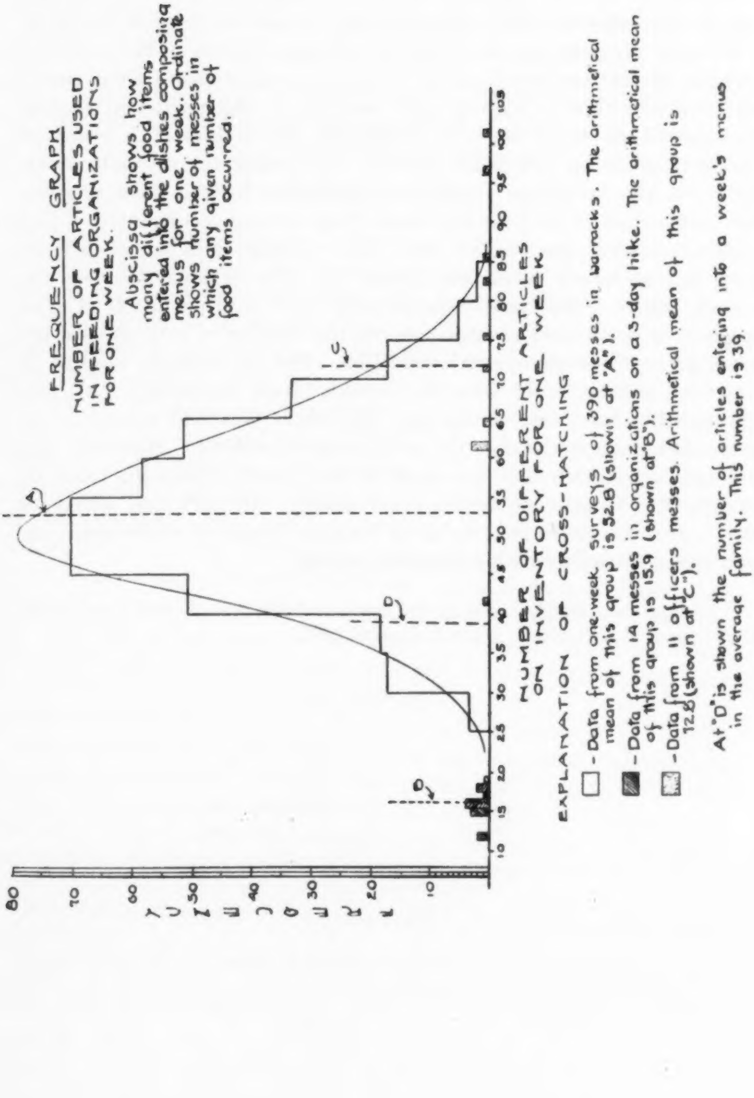

FREQUENCY GRAPH
NUMBER OF ARTICLES USED IN FEEDING ORGANIZATIONS FOR ONE WEEK.
Abscissa shows how many different food items entered into the dishes composing menus for one week. Ordinate shows number of messes in which any given number of food items occurred.
FREQUENCY
80 70 60 50 40 30 20 10
10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105
A
B
C
D
NUMBER OF DIFFERENT ARTICLES ON INVENTORY FOR ONE WEEK
EXPLANATION OF CROSS-MATCHING
- Data from one-week surveys of 390 messes in barracks. The arithmetical mean of this group is 52.8 (shown at "A").
- Data from 14 messes in organizations on a 3-day hike. The arithmetical mean of this group is 15.9 (shown at "B").
- Data from 11 officers messes. Arithmetical mean of this group is 72.8 (shown at "C").
At "D" is shown the number of articles entering into a week's menus in the average family. This number is 39.

Chart 11

VARIETY

One of the most important factors in the diet for the maintenance of morale is variety. In studying this question one is met at the outset by the difficulty of assigning a value to such a factor in the mess. The most obvious way in which to measure variety is to count the number of different articles of food on the inventory for a given period and consider this an approximate measure of this particular dietary factor. Chart 11 represents graphically the results of a study of this sort made on 390 army messes. In making the estimate of articles on the inventory everything purchased by the mess sergeant for preparation of food for the week of the survey was counted. This included spices, tea, coffee, etc. The average number of articles used per mess per week was about 55. For organizations on the march, where difficulties of preparation and transportation of food necessarily demanded a simpler menu, the number of articles used per mess for a three-day period was 15.9. For an average family[4] 39 different articles enter into the weekly food inventory. At first glance, therefore, one would say that there was less monotony in army diet than in the diet of the average household. However, it is not entirely certain that the count of household articles was made on exactly the same basis as the army count. All that may safely be said is that army feeding, so far at least as variety is concerned, compares very favorably with household feeding.

[4] From dietary studies made by the Bureau of Markets of the United States Department of Agriculture in the autumn of 1917.

VARIATIONS IN STRENGTH AND IN THE CONSUMPTION OF FOOD BY RECRUITS AND SEASONED TROOPS

PAUL E. HOWE, C. C. MASON AND SANFORD C. DINSMORE

From the Section of Food and Nutrition, Division of Sanitation, Medical Department, United States Army

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Nutritional Survey Party no. 2[1] of the Division of Food and Nutrition was asked to take up the question of the use of the Martin (1) strength test as a practical means of classifying and assigning men for particular duties in the army and as a means of studying problems relating to food consumption. Preliminary tests were made at Camp Fremont, California with the aid of Dr. E. G. Martin. At our next station, Camp Lewis, Washington, the tests and surveys detailed in this paper were carried out to determine whether or not there is a relation between the food consumption and variation in strength of recruits. Due to certain difficulties, the original object of the work was not attained. The results are, however, of considerable value with regard to *a*, the variation in strength and weight of recruits during the first weeks in camp, and *b*, the variation in food consumption of the same group of men from week to week in the course of three and four weeks and of different groups of men at the same time and under almost identical conditions. Such data are of use in connection with the evaluation of studies of groups of people.[2]

Determinations were made of the variations in strength and of weight of approximately forty men from each of eight companies of recruits; Company 6 of the Depot Brigade was quarantined during part of the time and the results are not included in the strength tests. The studies extended for three consecutive weeks; a smaller number of men were continued for the fourth week. Weights and strength were determined

[1] Capt. Paul E. Howe, Lieut. C. C. Mason, Lieut. S. C. Dinsmore and Lieut. B. H. Harrison.

[2] The question of the number or length of studies of this nature which must be made to obtain a correct estimate of the *average* food consumption has been treated by Lt. Col. J. R. Murlin (2).

at seven-day intervals. The food consumption of the messes from which the men were selected for strength tests was determined in weekly periods. The men were inoculated and vaccinated during the first two weeks of study.

The recruits arrived at the camp between April 25 and April 28, 1918. They passed through the usual routine of physical examination, and were inoculated with vaccine against typhoid and small pox. The men lived in barracks and received their preliminary training during the time of observation. During the first two weeks they were in quarantine. The character of the work varied from day to day but was nearly uniform for all companies on the same day. No work was done on the day following inoculation. The mean temperature was practically constant throughout the work. Two of the most influential factors affecting the quantity and quality of food consumed in an army mess, the menu prepared by the mess sergeant and the character of the cooking, were at least in part minimized through the use of the same menu for each of two groups of four companies and by the presence of trained cooks belonging to the School for Bakers and Cooks, who were permanent members of the Depot Brigade. The cooks were under the constant supervision of a sergeant cook-instructor detailed to us to supervise the cooking. We feel therefore that the factors affecting food consumption aside from the inclination of the men to eat what was put before them were eliminated as much as can be expected.

The men of Companies I, K, L and M of the 364th Infantry represented seasoned troops; they had been in the organization since October 1917 and this work was conducted in April and May, 1918. These men had received the maximum of training given in this country. All the companies were in the same battalion and did practically the same work. No attempt was made to control the menus in these organizations since all were well established.

Strength tests. Data with regard to the strength tests are given in tables 1, 2 and 3, pages, 559, 560 and 561. Ten tests were made on each man (right and left pectorals, right and left wrist flexors, right and left forearm flexors, right and left thigh abductors, and right and left thigh adductors). The results according to Martin represented 17.7 per cent of a man's strength. The choice of the men was made directly from the rolls without knowledge of individual sizes or weights. Men with venereal diseases were excluded.

The following facts will be found from an examination of the data:

TABLE 1

Average variations in strength of individual companies, expressed as pounds pulled per man, and in weight, 166th Depot Brigade

PERIOD	NUMBER OF MEN	VACCINATION DAYS BEFORE TEST	WEIGHT	STRENGTH				TOTAL
				Pectoral	Wrist flexors	Forearm flexors	Thigh abductors adductors	
Company 5								
			pounds					
1	35	3	156	135	61	97	67	844
2	35	3	156	125	42	91	59	750
3	35	3	158	125	57	95	59	797
Company 7								
1	34	6	158	118	36	90	52	694
2	34	6	151	115	42	95	55	724
3	34	6	157	133	47	96	54	790
Company 8								
1	33	5	158	126	49	95	65	824
2	33	5	157	111	42	86	56	723
3	33	5	157	114	50	92	61	773
Company 9								
1	34	6	150	114	38	85	55	695
2	34	6	149	110	42	86	53	689
3	34	6	151	118	45	91	57	734
Company 10								
1	35	5	151	118	42	88	57	726
2	35	5	152	115	42	87	54	702
3	35	5	153	125	46	93	62	775
Company 11								
1	35	4	151	121	52	94	56	798
2	35	4	151	114	42	85	53	690
3	35	4	151	109	42	86	49	668

TABLE 1—*Continued*

PERIOD	NUMBER OF MEN	VACCINATION DAYS BEFORE TEST	WEIGHT	STRENGTH				TOTAL
				Pectoral	Wrist flexors	Forearm flexors	Thigh abductors adductors	
Company 12								
			pounds					
1	26	2	154	120	62	92	54	761
2	26	2	154	116	42	83	55	698
3	26	2	156	110	55	85	51	700
Company K 364th Infantry								
1	24	—	152	132	64	94	52	789
2	24	—	152	123	57	85	49	724
3	24	—	153	121	57	92	47	726

Note: Average values for muscle groups represent pull for a single group of muscles, e.g., right pectoral, left thigh abductor.

TABLE 2

Average values for total strength as pounds pulled per man for men tested on four successive periods

ORGANIZATION	NUMBER OF MEN	STRENGTH 1	STRENGTH 2	STRENGTH 3	STRENGTH 4	WEIGHT 1	WEIGHT 2	WEIGHT 3	WEIGHT 4
Company 5	32	846	762	802	800	156	156	156	157
Company 7	14	711	730	793	738	157	154	156	157
Company 8	24	810	706	753	804	152	152	151	152
Company 9	17	684	670	720	705	147	147	149	155
Company 10	13	701	678	752	732	145	145	146	147
Company 11	9	709	635	632	701	151	150	152	152
Company 12	24	770	704	708	760	154	154	156	157
Company K, 364th Infantry	24	789	724	726		152	152	153	

Values for strength represent the sum of the actual weights pulled or 17.7 per cent of total strength according to Martin.

a. Every company, except Company 10, showed an initial loss in weight averaging 1 pound. By the end of the third week there was an average gain of one pound over the original weight.[3]

[3] Similar losses and gains, but of greater magnitude, were observed by Lieut. W. A. Perlzweig in his studies of recruits.

TABLE 3

Average results obtained from all strength tests on the 166th Depot Brigade, expressed as pounds pulled per man

PERIOD	NUMBER OF MEN	WEIGHT	STRENGTH				TOTAL
			Pectoral	Wrist flexors	Forearm flexors	Thigh abductors adductors	
A. All men							
1	232	153	122	48	92	57	760
2	232	152	115	42	88	55	708
3	232	154	119	48	91	57	746
B. Men tested four times							
1	133	152	123	51	92	59	768
2	133	152	116	41	88	55	710
3	133	153	118	51	91	57	748
4	133	155	125	47	92	58	761

b. Data with regard to strength show an initial loss with recovery practically completed by the third week and then strength held during the fourth week.

The men were at low ebb physically at about the end of the second week. The second injection had been given, they were not fully accustomed to the new life, they were all tired from the unusual drill and most of them were more or less homesick. We noted in making the tests that the second one aroused little interest.

By the time of the third test most of the men had returned nearly to normal and their mental attitude had improved. The results are reflected in the strength tests. The data obtained from a smaller number of men in the fourth week bear out the fact that recovery was practically complete by the third week.

An analysis of the percentage losses and gains in strength of the various muscle groups tested with relation to the total weight pulled on the first test shows the following average results:

PERIOD	PECTORALS	WRIST FLEXORS	FOREARM FLEXORS	THIGH ABDUCTORS ADDUCTORS
2	−0.6	−0.8	−0.5	−0.4
3	+0.4	+0.8	+0.5	+0.3

TABLE 4

Average food consumption per man per day during three successive weeks, 166th Depot Brigade

	PROTEINS	FAT	CARBOHYDRATES	CALORIES
Company 5, 4/30–5/6/18	126	124	546	3912
5/7–5/13/18	110	121	457	3448
5/14–5/20/18	126	121	543	3863
Average	121	122	515	3741
Company 6, 4/30–5/6/18	104	117	421	3241
5/7–5/13/18	110	127	466	3538
5/14–5/20/18	102	113	407	3145
Average	105	119	431	3308
Company 7, 4/30–5/6/18	89	111	375	2931
5/7–5/13/18	100	130	349	3046
5/14–5/20/18	127	152	423	3669
Average	105	131	382	3215
Company 8, 4/30–5/6/18	155	172	495	4264
5/7–5/13/18	82	91	335	2557
5/14–5/20/18	134	133	598	4244
Average	124	132	476	3688
Company 9, 4/30–5/6/18	90	82	420	2852
5/7–5/13/18	110	116	482	3505
5/14–5/20/18	147	141	533	4096
Average	116	113	478	3484
Company 10, 4/30–5/6/18	85	75	517	3162
5/7–5/13/18	119	121	395	3231
5/14–5/20/18	115	112	525	3661
Average	106	103	479	3351
Company 11, 4/30–5/6/18	108	72	465	3022
5/7–5/13/18	115	93	538	3542
5/14–5/20/18	97	92	397	2879
Average	107	86	467	3148
Company 12, 4/30–5/6/18	129	108	627	4105
5/7–5/13/18	106	103	421	3119
5/14–5/20/18	118	106	518	3591
Average	118	106	522	3605
Average of all	112	114	469	3483

The percentage losses in the second week are practically made up in the third week. The wrists show the greatest loss; the men had just received their rifles at this time and this may be a factor.

There does not appear to be a direct relation between loss in strength and the proximity to the time of inoculation.

TABLE 5

Average food consumption per man per day during four successive weeks, 364th Infantry, seasoned troops

	PROTEINS	FAT	CARBOHYDRATES	CALORIES
Company I, 4/23–4/29/18	133	150	555	4212
4/30–5/ 6/18	139	153	522	4127
5/ 7–5/13/18	125	117	604	4074
5/14–5/20/18	113	98	526	3527
Average	128	130	552	3985
Company K, 4/23–4/29/18	100	102	535	3548
4/30–5/ 6/18	142	151	485	3972
5/ 7–5/13/18	112	119	603	4034
5/14–5/20/18	132	106	543	3752
Average	123	120	542	3827
Company L, 4/23–4/29/18	125	142	475	3778
4/30–5/ 6/18	156	136	560	4200
5/ 7–5/13/18	127	120	483	3616
5/14–5/20/18	116	117	429	3322
Average	131	124	487	3729
Company M, 4/23–4/29/18	149	133	510	3936
4/30–5/ 6/18	113	109	427	3230
5/ 7–5/13/18	123	124	448	3497
5/14–5/20/18	116	110	459	3385
Average	125	119	461	3512
Average of all	126	124	510	3764

The results on Company K, 364th Infantry, are not of value for comparison with the Depot Brigade for the training schedule prevented our getting the men in approximately the same condition for the different tests. In the second and third tests the men were fatigued as the result of active and heavy work. The values obtained indicate the effect of fatigue.

TABLE 6

Average food consumption of different companies using the same menu at the same time. 166th Depot Brigade

DATE		PROTEINS	FAT	CARBO-HYDRATES	CALORIES
4/30–5/7/18	Company 5	126.0	124.0	546.0	3912
	Company 6	104.0	117.0	421.0	3241
	Company 7	89.0	111.0	375.0	2931
	Company 8	155.0	172.0	495.0	4264
	Average	118.5	131.0	457.5	3587
	Company 9	90.0	82.0	420.0	2852
	Company 10	85.0	75.0	517.0	3162
	Company 11	108.0	72.0	465.0	3022
	Company 12	129.0	108.0	627.0	4105
	Average	103.0	84.0	507.0	3285
5/7–5/13/18	Company 5	110.0	121.0	457.0	3448
	Company 6	110.0	127.0	466.0	3538
	Company 7	100.0	130.0	349.0	3046
	Company 8	82.0	91.0	335.0	2557
	Average	100.5	117.0	402.0	3147
	Company 9	110.0	116.0	482.0	3505
	Company 10	119.0	121.0	395.0	3231
	Company 11	115.0	93.0	538.0	3542
	Company 12	106.0	103.0	421.0	3119
	Average	110.0	108.0	459.0	3349
5/14–5/20/18	Company 5	126.0	121.0	543.0	3863
	Company 6	102.0	113.0	407.0	3145
	Company 7	127.0	152.0	423.0	3669
	Company 8	134.0	133.0	598.0	4244
	Average	122.0	129.7	492.7	3730
	Company 9	147.0	141.0	533.0	4096
	Company 10	115.0	112.0	525.0	3661
	Company 11	97.0	92.0	397.0	2879
	Company 12	118.0	106.0	518.0	3591
	Average	119.0	112.7	493.0	3557
	Average of all studies	112.2	114.0	469.0	3483

Food consumption. The data relating to the food consumption are included in tables 4, 5, 6 and 7, pages 562, 563, 564 and 565. Tables 4 and 5 give the data from the same companies in each of successive periods. Tables 6 gives the results obtained for the same groups of companies when using the same menu. Table 7 gives the average values for each company during the periods studied.

TABLE 7

Company average food consumption per man per day for 3 one-week periods, 166th Depot Brigade, and 4 one-week periods, 364th Infantry

	PROTEINS	FAT	CARBOHYDRATES	CALORIES
166th Depot Brigade. 3 one-week periods, 24 studies				
Company 5	121	122	515	3741
Company 6	105	119	431	3308
Company 7	105	131	382	3215
Company 8	124	132	476	3688
Company 9	116	113	478	3484
Company 10	106	103	479	3351
Company 11	107	86	467	3148
Company 12	118	106	522	3605
Average Depot Brigade	112	114	469	3483
364th Infantry. 4 one-week periods, 16 studies				
Company I	128	130	552	3985
Company K	123	120	542	3827
Company L	131	124	487	3729
Company M	125	119	461	3512
Average, Infantry Companies	126	124	510	3764
Grand average, 40 studies	118	118	485	3573

In considering the data it is to be remembered that each weekly average represents the average of the food consumed by approximately 220 men or equivalent to 1540 men for one day. The results are particularly interesting in that they give some indication of the variable food consumption which may exist under the very similar conditions. Even when using essentially the same kinds of food in the form of similar dishes there is a variation in the food consumption of different groups of men.

That the results are characteristic of recruits is not borne out by the results obtained in the 364th Infantry, for here we find just as great variations as with the recruits. The average food consumption is somewhat higher, a fact which is substantiated by other data obtained by the Division of Food and Nutrition.

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NOTE ON THE ACID-BASE BALANCE OF ARMY RATIONS

N. R. BLATHERWICK

From the Section of Food and Nutrition, Division of Sanitation, Medical Department, United States Army

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Interest in the acid-base balance of dietaries has increased greatly in recent years. Sherman and his collaborators gave us the basis for work along this line when they made more accurate determinations than had hitherto been available of the ash constituents of the common foods. It will be recalled that meats and cereals show a predominance of acid-forming elements, while on the other hand fruits and vegetables have an excess of base-forming elements. Working under the direction of Professor Mendel, (1) it was my privilege to demonstrate the specific influence of the ash of foods upon the composition of the urine. This study showed that acid-forming foods lead to the formation of more acid urines and base-forming foods cause the excretion of less acid or alkaline urines. Certain exceptions were found, namely, plums, prunes and cranberries, which although yielding a basic ash, nevertheless increase the acid excretion due to the presence of benzoic acid, excreted as hippuric acid.

Although the question, whether or not an acid-forming diet eaten for some period of time is productive of undesirable results is debatable, probably the consensus of opinion is in favor of diets in which the acid-forming and base-forming elements are approximately balanced. Accepting this, it then becomes a matter of importance to determine whether soldiers' rations are well balanced in this sense.

Our soldiers in the training camps are subsisted on what is known as the garrison ration, the chief components of which are fresh beef, flour and potatoes. This ration, when completely eaten, is abundant in protein and energy content and shows an excess of acid-forming elements corresponding to about 44 cc. N/1 solution per day. Owing to the ration savings privilege, the mess sergeant is able to decrease the amounts of the various components consumed and receives credit for the same from the supply officer. With the money thus obtained,

TABLE 1

Acid-base balance of army rations

CAMP	ORGANIZATION	MILLIGRAMS PER RATION			REACTION		PROTEIN CALORIES
		Ca	P	Fe	Excess Acid	Excess Base	
					cc. N/1	*cc. N/1*	*per cent*
Bowie	132 F. A.	572	2077		11		18
Chanute	267 A. S.	1045	2600			6	13
Cody	125 F. A.	666	2615	37.4	19		16
Devens	301 F. S. Bn.	834	2133	25.7		9	12
Devens	303 F. A.	1060	2279	28.7	12		17
Dix	303 Eng.	691	1983			14	16
Dix	307 F. A.	556	2085	26.7		1	15
Funston	C. & B. School	780	2758	29.6	9		13
Greene	39 Inf.	653	2428	49.4	11		14
Greenleaf	Recr. No. 1	513	1645		28		10
Jackson	Off. Mess B. H.	782	1874			13	13
Johnston	Mess Co. No. 1	759	2229			24	14
Kearny	134 F. A.	685	1808			24	14
Lee	320 Inf.	643	2181	29.6	18		14
McClellan	112 H. F. A.	833	2065	30.2	4		15
Rockwell	63 Inf.	583	2140	29.1	13		16
Sevier	105 Eng.	649	2482	29.7	15		12
Selfridge	40 Squad.	749	1915	24.0		15	11
Gordon	2 Inf.	374	1516	22.8	0	0	15
Travis	260 Inf.	481	1975	23.3	39		14
Kelly	324 Squad.	627	2103	26.9	24		13
Fremont	12 Inf.	856	2050	30.3	1		12
Taylor	336 Inf.	956	2845	43.3	6		15
Scott	262 Squad.	695	2092	27.7	12		15
Upton	152 D. B.	573	2170	26.2		7	19
Wadsworth	107 Inf.	508	1992	24.3		1	15
Chanute	268 A. S.	868	2340	27.5	2		16
Gerstner	143 Squad.	659	1732	20.3			15
Lewis	166 D. B.	996	2632	34.4		20	15
Hazelhurst	357 A. S.	704	2215	29.4		13	13
Douglas	War prisoners	717	2130	25.0		25	13
Vancouver	404 A. Squad.	687	2402	26.7	19		14
Average		711	2171	29.1			14
Sherman's Standard		680	1440	15.0			

he purchases foods in the open market which give variety and, incidentally, serve to introduce larger amounts of the base-forming elements.[1] Table 1 shows in cubic centimeters of N/1 solution the excess of acid or base in the rations of various organizations from many camps. These values were obtained by determining the average amounts of all foods consumed per man per day for a period of seven days. Acid and base values were calculated from Sherman's tables. It is seen that some of the diets are strongly acid-forming, some about neutral and others contain an excess of base. There is, undoubtedly, a tendency for the rations, as actually consumed, to be acid-forming in character. The rations were found to contain more calcium, phosphorus and iron than the standards proposed by Sherman require.

TABLE 2

Acid-base balance of rations, Camp Cody

DATE	ORGANIZATION	Ca	P	Fe	EXCESS ACID	EXCESS BASE
		mgm.	*mgm.*	*mgm.*	*cc. N/1*	*cc. N/1*
August 3-9, 1918.........	Co. H, 135th Inf.	539	1790	22.1	30.2	
August 3-9, 1918.........	Co. I, 135th Inf.	416	1671	22.0	21.2	
August 3-9, 1918.........	Co. L., 135th Inf.	473	1662	21.0	21.5	
August 3-9, 1918.........	Co. M., 135th Inf.	542	1801	21.3	19.1	
August 11-17, 1918.......	Liquid Diet, Base Hosp.	1279	1240	67.0		21.0
August 11-17, 1918.......	Light Diet, Base Hosp.	872	2087	28.0		25.0
August 11-17, 1918.......	Patients' Mess, Base Hosp.	680	1585	23.0		2.0

Examination of base hospital dietaries reveals the interesting fact that base-forming elements are practically always in excess. Table 2 shows the acid-base balance of the rations of four infantry companies and of the base hospital diets at Camp Cody (data supplied by Capt. Paul E. Howe). This condition, perhaps, is more strikingly exhibited in a study made at the Base Hospital, Camp Custer, by Lieut. C. N. Frey, who undertook this work aided by the great interest of Lieut. Colonel Irons, the Commanding Officer. Table 3 indicates that the convalescent patients had only one of seven days in which the acid-forming elements of the food were in excess of the base formers. It seems significant that these hospital dietaries show such a marked contrast with many rations consumed by the well soldier. Is this alkaline reaction of the dietaries of the sick merely a coincidence, or

[1] Since April 1, 1919, all supplies have been obtained from the Quartermaster.

has a process of selection hit upon the seeming fact that neutral or base-forming diets are best suited to the needs of convalescents? The greater amounts of bases in hospital diets are secured by a more extensive use of milk, fruits and vegetables.

The possibility that the continued use of acid-forming diets may lead to a greater susceptibility to diseases of the less infectious type has seemed worthy of investigation. The statement of Hindhede (2) regarding his children who are vegetarians may be recalled, "I may add that with the exception of whooping cough and measles, which attacked them very lightly, and a slight tonsillitis in one of them, I do not recall that any of my children have ever been really ill."

TABLE 3

Summary of ration study, convalescent patients' mess, Base Hospital, Camp Custer

DAY	CALORIES (TOTAL)	ANIMAL PROTEIN	VEGETABLE PROTEIN	PROTEIN	EXCESS ACID	EXCESS BASE
		per cent	*per cent*	*grams*	*cc. N/1*	*cc. N/1*
Monday	3175	74.4	25.6	119		1.8
Tuesday	4258	65.1	34.9	117		15.6
Wednesday	3673	67.7	32.3	122	0.7	
Thursday	4418	59.0	41.0	146		113.0*
Friday	2855	61.3	38.7	109		4.1
Saturday	3690	59.2	40.8	109		25.0
Sunday	3420	76.0	24.0	132		24.4
Average	3638	66.1	33.9	122		30.6

* Foods contributing base: potatoes, spinach, milk, beans, figs, apples.

Chittenden has also reported a better state of health when living on a low protein diet.

At Camp Wheeler, conditions seemed favorable for undertaking an investigation of the possible relationship of diet to disease. During the winter of 1917–18, this camp had numerous cases of measles, mumps, influenza and pneumonia. When Nutritional Survey Party no. 8, under the leadership of Major H. A. Mattill, arrived there last spring, we were impressed with the peculiar dietary habits of the soldiers. A preliminary examination of the bills of fare showed that many organizations were consuming about one pound of meat per man per day and only about one-fourth pound of potatoes, instead of the usual pound of this food. Potatoes, with their alkaline ash, were substituted by rice and hominy, with their excess of acid-forming

elements. Chart 1 shows the relationship found between amounts of meat supplied and the duration of disease for fifteen companies of the 124th Infantry during February and March, 1918. A rough parallelism is indicated.

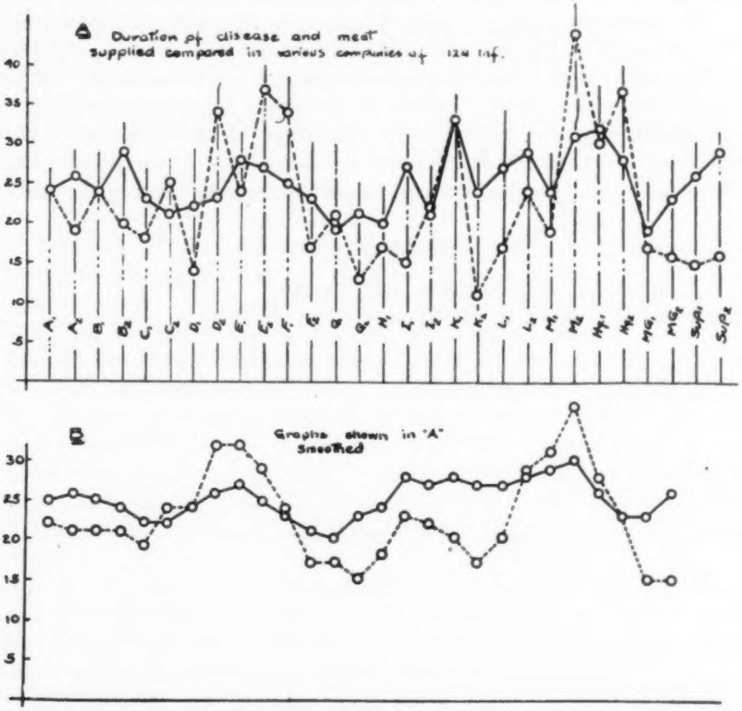

Fig. 1. A, Duration of disease and meat supplied compared in various companies of 124th Infantry; B, graphs shown in "A" smoothed. Solid line represents amount of meat supplied the messes, one scale division representing 4 pounds. Dotted line represents duration of disease.

The author studied the food consumption of certain organizations at Camp Devens during the epidemic of influenza-pneumonia. The three companies of the 36th Infantry with the lowest influenza rates and the three companies having the highest influenza rates failed to show any relationship whatsoever to the amount of excess acid in the rations (excess acid varied from 6.8 to 31.8 cc. N/1 solution per man

per day). Neither was any relationship between influenza rate and calorific intake or the partition of the calories indicated. It is extremely difficult, one might say impossible, to demonstrate any such influence in the case of influenza. The virulence of the organism or organisms is so great as to sweep away all ordinary powers of resistance.

The results obtained at Camp Wheeler are suggestive of a possibility that an acid-forming diet consumed for long periods of time may lead to a greater susceptibility to disease of the less infectious type. Those who have control of the feeding of the large numbers of persons in our public institutions might well undertake an investigation of this problem. In such institutions the necessary control of the diet and of the other factors should be more easily obtainable than in the army.

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DRIED VEGETABLES FOR ARMY USE

SAMUEL C. PRESCOTT

From the Section of Food and Nutrition, Division of Sanitation, Medical Department, United States Army

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A famous wit once remarked that there is nothing new except what has been forgotten. The period since 1914 has proved the aptness if not the truth of this remark, for the conservation of food by drying has been strongly urged as a "new" method, whereas in reality it is perhaps the oldest method of preserving foods extant. Even in their relations to army subsistence we cannot claim that the dried or, as we now are more likely to speak of them, "dehydrated," foods can claim the quality of novelty for they were used to some extent in our Civil War, and to a considerable extent by the British Forces in the Boer War, and had been largely used by the Allies before the United States became an active participant in the struggle of the past few years.

It is true, however, that the European war has forced on our attention the possibilities of drying as a commercial process of food preservation in much the same way that the Civil War emphasized the great applicability of canning to the general problem of subsistence.

By "dehydration" is understood the rapid removal of water from vegetables, fruits or other foods through evaporation by the use of air currents or vacuum combined with moderate heat, to such an extent that the resulting product generally feels dry to the touch, and is hard, brittle or condensed in character. Dehydrated vegetables do not contain in general more than 10 per cent of water. The cellular structure should be unchanged, the membranes remaining intact, and the cell contents losing only water. When cooked they will return to approximately the bulk, appearance and character of the material before drying. If prepared properly the color, flavor and texture of the products when cooked will be essentially as in cooked fresh material.

The vegetables here considered include those ordinarily purchasable only in fresh, green or canned condition, and do not include mature dried beans, peas, lentils, corn or other vegetables of similar character.

During the Civil War desiccated vegetables in compressed form were used somewhat sparingly with the intent of improving the army ration from a hygienic standpoint, and especially as a means of preventing outbreaks of scurvy among the troops fed almost continuously on salt pork, salt beef, hard bread and the few vegetables which could be secured in the surrounding country. Some of the desiccated foods were said to be good while others were said to be very unpalatable. Among the anti-scorbutics issued to the Army of the Potomac in three months in 1864 were 600 pounds desiccated potatoes, 5320 pounds mixed vegetables and 551,812 pounds dried apples.

The following extract from the report of operations of the Medical Department of the Army of the Potomac from its organization in July, 1861, until the change of Base to the James River in July, 1862, by Surgeon C. S. Tripler, U. S. A. Medical Director, shows the faith which was placed in the use of these products as a means of preventing scurvy:

> While still at the White House, I received a telegram from the front that scurvy had appeared in two brigades of the Army one of which were the regular troops. I could scarcely credit the accuracy of the information. I knew that the brigade had obeyed the orders issued in relation to the use of vegetables, and the manner of cooking their rations; still I did not think it prudent to disregard the report, and accordingly I telegraphed to Washington for lemons and potash. . . . .
>
> . . . . I investigated the report with regard to scurvy and found it to be erroneous. I, however, requested the Adjutant General to compel the men to use desiccated vegetables and to make soup daily. . . . .
>
> . . . . General Dana says he cannot comprehend why the men should have scurvy with their present ration; but I am informed that the desiccated vegetables are so disagreeable to the taste that the men cannot eat them. . . . Antiscorbutic ordered. . . . .

During the Boer War dried soup vegetables which had been stored in paraffined barrels for over fifteen years, were used by the troops, thus indicating the keeping quality of these dehydrated products.

For about a year and a half I have had opportunity to study products prepared by a large number of methods, as manufacturers have sent them to Washington for possible sale to the Government for army use. There is a marked difference in products which have been studied. They have been examined as to:

a. Physical appearance.

b. Soaking back properties, whether good, bad, fairly rapid, or very slow.

c. Keeping quality. Danger of invasion by moulds, bacteria and insects.

d. Action of enzymes.

e. Absorption of moisture from air.

f. Cooking quality. Retention or loss of flavor.

g. Effect of type of container on the character and keeping quality of the foods.

As has been stated, marked differences have been noted. The causes for these differences may be referred to age and quality of raw materials, methods of pre-treatment, methods and time of drying and conditions of storage after drying. It may be stated that to secure good dehydrated vegetables the raw material should be fresh and of first-class quality. The pre-treatment by steam or hot water dipping should be brief and carefully managed to avoid excessive changes and the time and method of drying should be so regulated as to prevent intense surface evaporation at the beginning of the drying period with the consequent "case hardening" or sealing over of the surfaces so as to prevent rapid loss of the water from the inner tissues.

In a report to the Surgeon General in January, 1918, I pointed out certain advantages which might accrue as a result of the extensive use of dried vegetables and fruits in army subsistence. Most of these advantages were economic and a few were distinctly nutritional. The principal gains from such use were:

1. Lower cost of actual units.
2. Great saving of space in transportation.
3. Guaranteed keeping quality with no loss by freezing or spoilage.
4. Saving of storage space and labor in camp.
5. Wider range of vegetable foods.
6. Generally improved diet, through increase in roughage, alkaline salts and variety of combinations possible.

In the early part of the war some apprehension was felt regarding the use of these products, and while this fear was unnecessarily great it was based on certain sound observations. The ordinary dried vegetables before the war were neither attractive in appearance, appetizing in flavor nor good in food quality. Improvements have gradually taken place in the methods of preparation during the past four years, however, and while the bulk of material made is still in-

ferior, it is possible to secure some dehydrated products of excellent appearance and flavor closely approximating that of the cooked fresh vegetable, and of practically unimpaired food value. This improvement has been brought about by the recognition of the fact that a dehydrated food is not merely dried, but the drying must be done in such a way as to preserve cellular structure, prevent undue decomposition by heat, and forestall changes by microbic agencies or by oxidizing, proteolytic or sucroclastic enzymes. Attention must also be paid to the age, quality and soundness of the raw materials and to the methods of preparation, rate of drying and sanitation of the finished product.

During the past two years there have been shipped for our forces overseas approximately 40,000 tons of these products, principally potatoes, but also carrots, turnips, onions and large quantities of soup mixtures of six to eight or more vegetables. While no special reports on the use of these products are obtainable at this time, I am indebted to officers of the Quartermaster Corps for the statement that these dried foods have resulted in great saving in labor and have been found fairly acceptable to the men, satisfactory to the subsistence officers and cooks, and in general an excellent and easily handled form of vegetable food. This too in spite of the poor quality due to haste in manufacture to meet the emergency, and a letting down in specifications.

Extended studies conducted by the Section of Food and Nutrition of the Surgeon General's Office, and later by the Division of Dehydration of the Bureau of Chemistry have shown that from the standpoint of general use in large masses, chemical analysis, fuel value and maintenance of bodily strength, properly made products are practically equal to fresh materials. Reports from a number of army hospitals and camp messes have demonstrated their practicability.

The main question from the nutritive standpoint is in relation to antiscorbutic and growth-promoting properties. During the siege of Kut in the Mesopotamian Campaign it was reported that some of the British forces were afflicted with scurvy as a result of the constant and exclusive use of dried foods. Animal investigation with guinea pigs has shown that a diet composed entirely of dried vegetables of non-acid character is greatly weakened in antiscorbutics or has lost them altogether, while with dried fruits of acid character, such as tomatoes, oranges and lemons, scurvy does not result even after long continued feeding. With rats different results are obtained

and it seems to be practically impossible to produce symptoms of scurvy with any dried vegetables, if I am correctly informed. The bearing of these results on the use of these foods for the army, while of interest in a general way, is of secondary importance for it is only under most unusual conditions that a diet would be made up entirely of dried foods and then only for limited time periods. No experiments have been conducted on human subjects as would seem to be extremely desirable before we come to any final conclusion as to the deficiencies of these dried foods in antiscorbutic substances when applied to general use. The findings are of sufficient interest, however, to stimulate investigations for the purpose of discovering whether slight changes in the method of preparation or drying may not entirely overcome this academic objection and plans are now being formulated to take up these investigations on a large scale by the Division of Dehydration. Whether the mere presence of oxy-acids of the malic type is sufficient to prevent scurvy is problematical, but at least it seems probable that foods designed for use in localities where it is impossible to secure any fresh material can be so treated by changes in pre-treatment, by fermentation or otherwise as to secure the necessary antiscorbutic substance.

With a reduction in weight amounting to 90 per cent in most cases, a reduction in bulk amounting to more than 50 per cent and a guarantee of keeping qualities for long continued periods and the obviously greater ease of transportation, the military advantages in the use of these foods are so great that there can be no doubt but the army will constantly make use of them in increasing quantity for all expeditionary forces and in posts and camps during the winter and when an abundant and cheap supply of fresh materials cannot be obtained.

AMERICAN MILITARY HOSPITAL DIETARIES[1]

R. G. HOSKINS

From the Section of Food and Nutrition, Division of Sanitation, Medical Department, United States Army

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The problems of military hospital nutrition are, in general, much like those of any large institution, i.e., problems of supply, preparation and distribution. There are, however, certain features in the military hospitals not generally observed in civilian institutions. These arise mostly from the superposition of a military regime on that of an ordinary hospital. The proportion of patients who are practically well and merely waiting for discharge is notably higher in military than in civilian hospitals, these being essentially normal men, temporarily in confinement. The per capita food consumption, therefore, averages relatively high. The fact that the patients are subject to a high degree of arbitrary control is also reflected in totals of consumption and waste.

Although there are certain variations in details, the general plan of administration of the base and general hospitals in this country at present is much the same in all. Directly under the commanding officer is the mess officer, usually either an experienced hotel manager, or a former army mess sergeant commissioned in the Sanitary Corps. Associated with him, sometimes under his immediate direction, and sometimes immediately under the commanding officer, is the dietitian. She usually has one or more assistants. The dietitians are, for the most part, women who have had courses in domestic science, but who often have had little or no previous training in hospital work. The mess officer has the assistance of several sergeants who deal with such

[1] The quantitative data herein reported have been collected by several survey parties of the Section of Food and Nutrition, Office of the Surgeon General. Since thirty or more individuals have contributed, it is not feasible to assign credit, except for certain specific studies. The field notes added by the writer have been accumulated in the course of nine months' study of nutritional problems in some fifty military hospitals.

matters as supplies, accounts and kitchen and dining room management. The actual preparation of the food, and the care of the utensils and the premises are attended to by cooks, usually enlisted men, and kitchen police. Separate messes are typically maintained for sick officers, nurses, enlisted men, patients and hospital corps men. The officers' mess proper, and the nurses' mess are usually quasi-independent institutions, in which, however, the mess organization takes a benevolent and coöperating interest.

In theory, at any rate, dietetics is a branch of therapeutics, and each soldier in the hospital should receive the diet best adapted to his case, just as he should receive individual therapeusis in other respects. Practically, however, conditions have not permitted anything very closely approximating this ideal. It is true that occasionally special diets are encountered, which have been devised for individual patients, but for the most part, conventional "lights," "liquids" and "regulars" are provided for the men in large groups, with, in some cases "softs" interposed between the "liquids" and "lights," especially for the surgical convalescents. This is not an ideal state of affairs, but under existing conditions is probably as satisfactory as can be hoped for. The problem then resolves itself into one of best utilizing this system to secure for each patient the diet best suited to his individual needs.

Exclusive of officers and nurses, there are, from the point of view of dietetics, at least eight classes of individuals to be dealt with. These are:

1. Normal men at fairly active work, needing approximately 3600 calories daily.

2. Normal men at sedentary work, needing approximately 3200 calories each.

3. Convalescent patients, metabolically normal, walking about the wards and requiring approximately 2600 calories. Aside from a rather low caloric demand, there are no special indications to be met in the diet of this class.

4. Bed patients, metabolically normal, requiring approximately 2000 calories. This class is usually over-fed, receiving meals intended primarily for class 3, or even classes 1 and 2.

5. Sub-acute febrile patients, those with empyema especially, needing high caloric and high-protein feeding. Experience at Camp Lee has shown that empyema results in a constant drain on the body nitrogen, which should be compensated in the diet. The specific

dynamic action of protein is probably also of importance in this type of patients.

6. In this class may be included a considerable variety of patients who are not sufficiently ill to receive special diets, but whose convalescence could be hastened by careful attention to their dietaries. They include convalescents from pneumonia, and others in poor physical trim, who need a fairly generous diet, but who, from lack of appetite, eat but sparingly. Such patients should have meals planned especially for attractiveness and high caloric content. A common practice is to give these men the ordinary regular diet, supplemented by egg nogs and other special foods between meals. This is a makeshift device, which has obvious defects.

7. For that class of patients troubled with constipation when not actively exercising, a diet including especially laxative components should be provided. Rather than establishing a special diet for this type of patients, however, the situation could be met fairly well by deliberately making the meals of all regular patients laxative. The routine use of cathartics in the wards is a reflection upon the dietitians.

8. There is, of course, a special group of diseases, including nephritis, diabetes, cardio-vascular disorders, gastro-intestinal and acute surgical cases, which by general consent must be treated by special dietary therapeusis. The problem of meeting the needs of such cases does not ordinarily confront the mess administration, since the diets usually are, and should be prescribed by the surgeons in charge.

In table 1 are included the quantitative data available on food consumption in army hospitals and medical organizations. The number of rations upon which the study in each case is based, is stated in column 3. This, it will be seen, varies from 131 to 15,897. The ration, it might be stated, comprises the food of one man for one day. The studies have usually been carried out for a period of one week. In making such studies, the general plan has been to invoice the food materials in the kitchen and store rooms at the beginning of the study, to record all accessions during the period, and to make a second inventory at the end. Subtracting the amount at the second inventory from the sum of the first inventory and the accessions gave the food used during the period. From this were subtracted the various components of the garbage, giving the actual consumption during the period. In certain of the hospital studies, a more direct method of weighing the food actually used was more practicable.

TABLE 1

PATIENTS	TYPE OF HOSPITAL	RATIONS TOTAL FOR PERIOD STUDIED	NUMBER CALORIES CONSUMED	DISTRIBUTION P.	DISTRIBUTION F.	DISTRIBUTION C.	COST PER DAY	COST PER 1000 CALORIES	EDIBLE WASTE P. M. P. D.
				per cent	*per cent*	*per cent*	*cents*		*pounds*
Liquid diets	Base	537	900	14	36	50	17.37	19.30	None
Light diets	Base	2,254	2,535	13	24	63	41.97	13.93	0.78
	Base	1,480	1,916	16	33	51	47.31	20.06	0.68
Regular diets	Base	4,109	3,788	13	33	54	55.34	14.61	0.22
	Base	5,341	2,743	13	29	58	46.06	13.40	0.98
	Base	614	3,458	12	35	53	48.23	12.12	0.72
	Base	709	3,242	11	36	53	39.83	10.84	0.91
	Base	236	3,906	14	34	52	57.90	13.74	0.48
	Base	728	3,043	13	35	52	45.64	12.44	0.96
	Base	4,516	3,270	14	37	49	55.13	14.85	0.68
	Base	10,125	3,165	12	34	54	45.48	12.18	0.73
	Aviation	131	2,986	15	38	47	54.14	17.19	0.18
	Base	3,338	2,759	12	34	54	52.20	14.53	1.16
Average		29,827	3,236	13	35	53	49.99	13.59	0.70
Officers' ward	Base	137	3,570	15	39	46	77.47	18.65	0.71
Patients and corps men combined	General	2,391	3,629	13	30	57	43.03	11.17	0.30
	Aviation	318	3,998	10	36	54	55.73	13.15	0.29
	Base	3,310	2,624	17	32	51	39.50	14.32	0.19
	Field	386	3,605	13	26	61	35.42	9.48	0.19
Average		6,405	3,464	13	31	56	43.42	12.03	0.24
Non-patients									
Med. Det.	Base	2,581	3,863	12	39	49	59.05	13.78	0.53
Nurses	Base	791	2,859	14	31	55	40.72	13.01	0.35
Hosp. Det.	Base	1,392	3,472	12	24	64	36.89	9.54	No data
Hosp. Det.	Base	1,863	3,682	14	29	57	51.26	13.68	0.20
Officers	Base	513	3,695	12	39	49	52.58	13.96	0.91
122-106 S. Tr.	Field	354	3,714	13	34	53	54.11	12.37	0.84
123 F. Hosp.	Field	248	4,047	14	36	50	57.08	12.67	0.64
F. Hosp.	Field	519	3,407	14	32	54	35.89	10.07	0.23
141 F. Hosp.	Field	556	3,387	12	35	53	40.15	11.60	0.09
Hosp. Corps	Aviation	187	4,522	13	31	56	58.50	12.58	0.12
U. S. A. A. S.		15,897	4,052	15	39	46	67.58	14.72	0.80
Sanitary Co.		1,148	3,638	13	31	56	47.80	11.73	0.71
Sanitary Co.		1,467	4,145	13	25	68	44.40	9.97	0.64
Amb. Co.		697	4,637	13	31	56	51.50	10.68	0.19
Amb. Co.		841	4,880	12	41	47	51.91	10.21	0.32
Amb. Co.		399	3,778	11	36	53	39.66	9.77	0.35
Amb. Co.		714	2,992	14	33	53	48.07	15.54	0.09
Amb. Co.		819	4,000	13	30	57	46.67	11.34	0.17
Amb. Co.		723	3,962	14	34	52	55.12	13.51	0.22
Average		31,709	3,828	13	33	54	49.94	12.14	0.39
Average of 427 army messes			3,633	14	31	55	47.26	13.01	0.38

One study of liquid diets only is available. In this the caloric content amounted to 900, with a fairly normal distribution of protein, fat and carbohydrate. Such diets are generally used for but a short time, and from a nutritional point of view often amount to little more than agreeable fluids.

Light diets in two hospitals, including 3734 rations, were studied. The caloric consumption in one was 2535, and in the other, 1916. The protein components amounted to 15 per cent as compared with an average of 14 per cent in 427 army messes elsewhere summarized. The fat components averaged 29 per cent, as compared with 31 per cent in the average army mess. Even this proportion seems somewhat high, however, for a "light" diet. The fact that such diets usually comprise considerable amounts of milk and eggs accounts for the cost of 45 cents per day, as compared with 47 cents for a full 3600 calorie ration. The edible waste in this group amounted to 0.73 pound per man per day. This is somewhat high as compared with average hospital waste, and is about twice that of the average army mess. This is to be ascribed partially to the capricious appetites characteristic of men ill enough to require light diets and partially to inefficiency in serving. This waste can be held at a much lower level.

Of the regular diets, ten studies are available, comprising 29,827 rations. The caloric consumption varied from 2743 to 3906, averaging 3236. The protein and carbohydrate components were slightly below the army average, while the fat component amounted to 35 per cent as compared with 31 per cent in the average army mess. This is to be ascribed partly to a higher consumption of butter and cream, but also, unfortunately, partly to unskilful dietaries in which greasy food played a part. The edible waste in this group was 0.7 pound per man per day. Experience at the Camp Custer Base Hospital has shown that the edible waste can be held below 0.3 ounce per man per day.

Only one study of a sick officers' ward is available. This comprised 137 rations. The caloric consumption amounted to 3570, which is probably somewhat below the average for this type of patients. The writer has been struck by the frequency with which officers in hospital systematically overeat. Heavy breakfasts, such as bacon and eggs, cereal with cream, fruit, potato and coffee with cream and sugar, are the usual type. The dinners and suppers are correspondingly generous. The fat consumption in the study reported, it will be noted, is 39 per cent, as against a general army average of 31 per cent. It is generally recognized by the dietitians and mess officers that such diets

are highly improper for sick men, but the demand is insistent, and officer patients are likely to get approximately what they want. The edible waste in this particular study was 0.7 pound per man per day. This is probably less than average. No specific figures are available, but the waste in the officers' messes is notoriously higher than that of others in the army. The cost per day in this case was 77 cents, whereas the allowance for this type of patient is $1.00 per day.

In a considerable number of hospitals, owing to ignorance and indolence in some cases, and to lack of equipment in others, the hospital attendants and the patients have been fed the same meals. Four studies of such hospitals are available, comprising 6405 rations. The caloric consumption was 3464, which is intermediate between that of patients proper and of medical personnel. The fat consumption was normal; the protein slightly low and the carbohydrate correspondingly high. The waste in this group averaged 0.24 pound per day. This favorable figure is not representative of this type of mess. The highest waste seen in any hospitals has been found in those in which the sick and well men are fed together. In one case it amounted to approximately 2 pounds per man per day.

Of non-patient groups, nineteen studies have been treated together. These include medical detachment, nurses, officers, sanitary train, field hospital, ambulance section and ambulance companies, giving a total of 31,709 rations. The caloric consumption varied from 2859 to 4880 averaging 3828, and the distribution of protein, fat and carbohydrate was approximately normal but with fat slightly high. The cost per day and the edible waste per capita were slightly above the army average.

In the nurses' mess it will be noted that the caloric consumption amounted to but 2859, distributed in exactly the ratio found as average in 427 army messes. It is believed that this mess is fairly typical of its kind. An officers' mess comprising 513 rations is also included; in this class the caloric consumption was 3695. Observations in more than 50 such messes have convinced the writer that this amount is lower than average. It has been a matter of some interest to note the dietary idiosyncracies of medical officers. Over-consumption and inadequate balance are so common as to constitute the rule rather than the exception. The high wastage in such messes has been previously commented on.

In table 2 are summarized the results of a detailed ration study, made by Lieut. C. N. Frey at the Camp Custer Base Hospital. This table is interesting as showing the variability of a mess from one day to another. The low figure of 2855 calories consumed on Friday is to be ascribed, probably, to fish for dinner and for supper. This commodity is usually unpopular. In this hospital a special study has been made for months of the technique of waste control. The patients are well fed and contented and wastage almost eliminated. The edible waste for the week studied amounted to 0.26 ounce per capita daily, a quantity which might well serve as model for any institution or any home kitchen. This amounts to approximately 20 pounds of edible waste per thousand men, or 10 calories per capita.

TABLE 2

Summary of ration study

	Calories per man	Per cent calories protein	Per cent calories fat	Per cent calories carbohydrate	Per cent animal protein	Per cent vegetable protein	Pounds of food per day	Calories per pound of food issued	Edible waste per day average	Calories of food wasted, ounces	Per cent of calories of food issued wasted in garbage	Grams protein per man per day
Monday	3175	15	39	45	74	26	4.76	667	0.37	16.0	0.50	118.95
Tuesday	4258	11	47	42	65	35	6.04	705	0.25	11.0	0.25	117.13
Wednesday	3673	14	37	49	68	32	5.65	650	0.20	8.0	0.22	121.67
Thursday	4418	14	43	44	59	41	6.16	733	0.25	11.0	0.25	145.73
Friday	2855	16	28	56	61	39	5.60	510	0.25	8.0	0.28	108.96
Saturday	3690	12	35	53	59	41	5.69	647	0.25	10.0	0.37	108.90
Sunday	3420	16	38	46	76	24	6.02	559	0.25	9.0	0.27	131.60
Average	3638	14	38	48	66	44	5.70	639	0.26	10.3	0.305	121.85

In table 3 is summarized the result of a special study made by Lieut. A. G. Hogan in an ambulance company. The records of the men showed their weights at the time of enlistment; second weighings were made in connection with this study. It was found that the men had gained during their six months' service from September to March, an average of nine pounds each. The average height of the company was 172.8 cm.; the average weight was 67.3 kgm; the surface calculated by the DuBois formula amounted to 1.81 sq.m., giving a basal metabolism of 1725 calories. The total metabolism by actual quantitative

determination of the food consumption amounted to 3778 calories, leaving a difference of 2053, representing the activity metabolism. During the week of the study the weather was moderate, the time and place being early spring in Kentucky. The men in this company were by previous occupation mostly farmers and laborers.

TABLE 3

Metabolism of ambulance company, March 4, 1918

Gain in weight during service,—September to March	9.0 pounds
Average height	172.8 cm.
Average weight	67.3 kgm.
Surface, Du Bois Formula	1.81 sq. m.
Basal metabolism	1725 calories
Total metabolism, by consumption	3778 calories
Difference	2053 calories

Sixty-two men studied one week. Work, moderate; temperature, moderate. Previous occupation, largely farmers and laborers.

TABLE 4*

Average daily expenditure for certain foods for six months. August, 1918, to January, 1919, at Base Hospital, Camp Kearny, California

	MEAT	EGGS	FRESH MILK‡	BUTTER	FRESH FRUIT	FRESH VEGETABLES	CANNED MILK	TOTAL FOR 7 ITEMS	TOTAL EXPENDITURES
Patients' mess	13.1¢ 23.3%	5.5¢ 9.7%	7.3¢ 12.8%	3.4¢ 6.0%	1.9¢ 3.4%	4.3¢ 7.6%	2.8¢ 5.1%	38.3¢ 68.0%	56.4¢ 100.0%
Detachment's mess	17.6¢ 36.1%	4.4¢ 9.0%	0.8¢ 1.6%§	3.4¢ 6.9%	3.8¢ 7.7%	3.4¢ 7.0%	2.0¢ 4.0%	35.4¢ 72.0%	48.6¢ 100.0%
Officers' mess	33.8¢ 33.4%	8.3¢ 8.2%	12.9¢ 12.7%	6.5¢ 6.4%	9.9¢ 9.7%	6.9¢ 6.8%	1.7¢ 1.6%	80.0¢ 79.0%	101.0¢ 100.0%
Nurses' mess	10.3¢ 22.3%	3.3¢ 7.2%	6.6¢ 14.3%	3.8¢ 8.7%	4.1¢ 8.9%	3.9¢ 8.5%		32.0¢ 70.0%	46.1¢ 100.0%
Average 87 general messes	42.3%	4.4%	†	3.7%	†	6.0%	6.0%	62.4%	41.58%

* Compiled by Capt. Paul E. Howe, Sanitary Corps.

† Less than 1 per cent.

‡ Including cream and ice cream.

§ Ice cream, only.

Although it is intended to supply at army hospitals everything needed for adequate nutrition, the actual ration allowance for the individual patient is, of course, arbitrarily fixed. One of the major problems confronting the mess officer, therefore, is how to spend a limited sum to the best advantage.

In figure 1 is shown the relative expenditure for each of the 35 components most commonly used in 87 army messes. In table 4 is summarized the average expenditure in the Camp Kearny Base Hospital

Fig. 1

for seven items comprising about 70 per cent of the total expenditure. These are based on daily determinations for a period of six months. This study was made by Capt. Paul E. Howe.

Figure 2 represents graphically the relative expenditure for each of the seven items in the patients', detachment's, officers', and nurses' messes respectively, as compared with the result for 87 general army messes. It will be noted that the hospital expenditure for meat and for condensed milk was less and that for eggs, fresh milk, butter and fresh fruits materially higher than that of the army at large. The expenditure for fresh vegetables was only slightly greater in the hospital.

On the whole, the table indicates a nearer approach to a proper balance in the hospital than in the army at large. In this it is representative of hospital consumption in general.

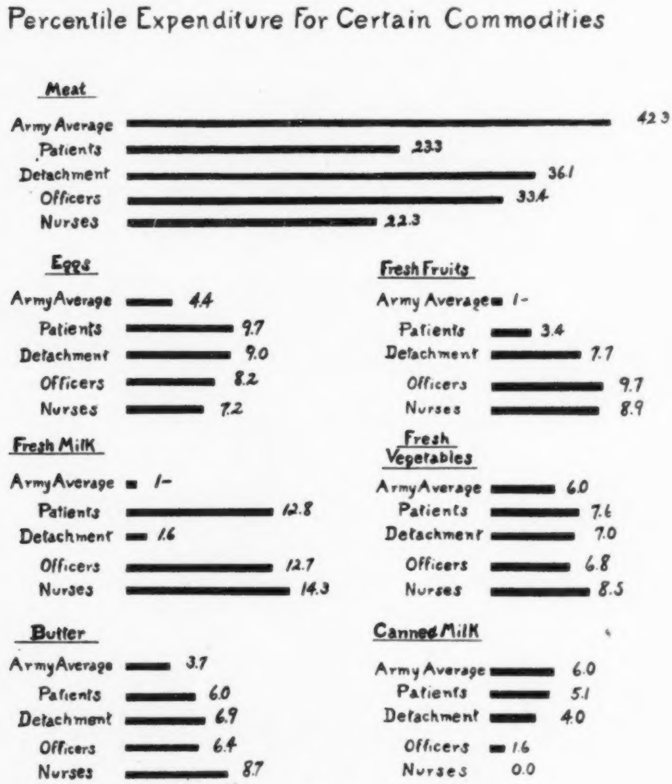

Fig. 2